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# An Evaluation System To Rate Feedlot Pollution Potential

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# **An Evaluation System To Rate Feedlot Pollution Potential**

Robert A. Young, Michael A. Otterby, and Amos Roos

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## Contents

List of tables .....	iv
List of figures .....	iv
Introduction .....	1
The Model .....	1
Local watershed .....	2
Rainfall .....	2
Pollutant indicators .....	3
Runoff .....	3
Equivalent animal units .....	4
Animal unit density and percent manure pack .....	4
Concentration of runoff at feedlot edge .....	4
Contact time .....	6
Pollutant reduction from filtration .....	6
Concentration reduction from dilution .....	7
Determining whether pollution hazard exists .....	7
Feedlot rating .....	7
Combining feedlot ratings .....	7
Limitations .....	8
Summary .....	9
Literature cited .....	10

## Appendix A

Feedlot screening procedure .....	12
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## Appendix B

Feedlot evaluation system—Feedlot screening .....	13
Screening instructions .....	14
Feedlot evaluation system—Preliminary evaluation data .....	15
First-level preliminary evaluation .....	15
Second-level preliminary evaluation .....	17
Feedlot evaluation system—Animal lot evaluation data .....	19

## Appendix C

Detailed instructions for calculations using the Hewlett-Packard	
97 calculator .....	30
Calculating animal lot screening .....	30
Calculating animal lot evaluation .....	30
Additional information available .....	32
Combined animal lot rating .....	34
Detailed instructions for calculations using the Monroe 335 calculator .....	35

## Appendix D

Calculator programs .....	44
Program for Hewlett-Packard 67/97/41C calculator .....	44
Screening program—Card1 .....	44
Evaluation program—Card 2.....	44
Evaluation program—Card 3.....	45
Additional information—Card 4.....	46
Combining ratings—Card 5.....	47
Preliminary evaluation—Card 6 .....	47
Program for Monroe 325/Compucorp 327 calculator .....	48
Screening program—Block 1 .....	48
Evaluation program—Block 2 .....	49
—Block 3 .....	51
—Block 4 .....	54
Combining ratings—Block 5 .....	56

## Appendix E

Manual calculations .....	57
User-oriented manual calculation procedure .....	58
Calculator-oriented manual calculation procedure .....	65

## Appendix F

Notes on the feedlot evaluation system .....	77
Interpreting animal lot ratings .....	77
Determining Area 3 and the discharge point .....	78
Buffer effectiveness.....	78
Evaluating manure stacks.....	78
Adjusting for loafing areas.....	78

## List of Tables

Table 1.—COD BOD ratios correlated in feedlot runoff . . . . .	3
Table 2.—Concentration of COD and P in runoff from feedlots . . . . .	5
Table 3.—Background concentrations of P and COD from various sources . . . . .	5

## Appendix B

Table 1.—Ratio of COD produced by various animals to that produced by a 1,000 pound slaughter steer . . . . .	13
Table 2.—Surface condition constant for various types of cover . . . . .	16
Table 3.—Ratio of COD produced by various animals to that produced by a 1,000 pound slaughter steer . . . . .	18
Table 4.—Surface condition constant and soil cover complex numbers for various cover condition . . . . .	23
Table 5.—Soil names and hydrologic classifications . . . . .	25
Table 6.—Ratio of COD and P produced by various animals to that produced by a 1,000 pound slaughter steer . . . . .	28

## List of Figures

Figure 1.—Local watershed . . . . .	2
Figure 2.—Percent manure pack versus animal unit density (AUD) . . . . .	4
Figure 3.—Concentration of COD and P in feedlot runoff versus percent manure pack . . . . .	5

## Appendix B

Figure 1.—25-year, 24-hour rainfall (inches) . . . . .	22
--	----

## Appendix E

Figure 1.— Soil-cover complex method of estimating direct runoff amounts from storm rainfall . . . . .	73
Figure 2.— Runoff velocity versus percent slope for various cover conditions . . . . .	74
Figure 3.— Reduction in pollutant strength (D) versus contact time ( $T_c$ ) for vegetated filter areas . . . . .	75
Figure 4.— Reduction in pollutant strength (D) versus contact time ( $T_c$ ) for grass waterways . . . . .	76

## Appendix F

Figure 1.— Examples of animal-lot watersheds . . . . .	77
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# An Evaluation System To Rate Feedlot Pollution Potential

Robert A. Young,<sup>1</sup> Michael A. Otterby,<sup>2</sup> and Amos Roos<sup>3</sup>

## Introduction

A uniform means of objectively evaluating potential pollution problems from animal feedlots has long been needed in Minnesota. Since 1971, the Minnesota Pollution Control Agency (MPCA), the State water quality agency, has had a permitting program for regulating feedlots. No standard method exists, however, for evaluating abatement measures of water pollution from feedlots and, consequently, MPCA felt a need for objective criteria to evaluate the water quality impacts of open feedlots.

In the past, dispensing of public funds for cost sharing to help alleviate pollution problems stemming from the operation of animal feedlots has usually been based on subjective evaluation by county committees or others responsible for their disbursement. Concrete guidelines or any uniform means of objectively evaluating these potential problems have been lacking. Specific guidelines are necessary for the equitable distribution of Federal and State cost-sharing funds to livestock producers. Such guidelines are necessary so limited funds will go as far as possible toward alleviating the severity of water pollution from feedlots.

Four Federal and State agencies—the Agricultural Stabilization and Conservation Service, the Soil Conservation Service (SCS), the State Soil and Water Conservation Board, and the MPCA—recognized the need to coordinate their animal waste control programs so that Federal and State cost-sharing funds, the Federal technical assistance program, and the State permit program could all work together to efficiently combat this source of potential pollution. MPCA, using a section 208 grant from the U.S. Environmental Protection Agency, gathered these agencies together, along with the cooperative extension service, in an advisory committee and contracted with the U.S. Department of Agriculture, Agricultural Research Service, to develop an animal waste-hazard analysis system. As a result, a system was developed that is impartial, relatively simple to operate, reasonably accurate, and is based on current research data. This system can be applied to any of the approximately 90,000 animal feedlot operations in the State of Minnesota.

## The Model

The animal lot evaluation system consists of two parts. The first, a short screening form (Appendix A), consists of five simple questions concerning an operation, all of which can be answered by the feedlot operator, allowing the person making the evaluation to disregard the feedlot immediately if it is definitely not a pollution hazard. Information from the first three questions deal with the pollution potential of surface

water, and the last two deal with the potential pollution hazard to ground water. Answers to the first three questions relating to surface-water pollution can be fed into a small desktop, programmable calculator, which uses a short program (Appendix D) to get a preliminary indication of whether or not a pollution hazard exists. If no calculator is available, a simple manual calculation will provide the same result. The methods used in this program or calculation procedure are discussed in Appendix A.

If, after completing the screening calculations, no apparent pollution hazard is indicated, no further evaluation is necessary. However, if the screening procedure indicates a potential hazard, then a more detailed evaluation form must be completed (Appendix B).

To carry out screening on the basis of information readily available to the feedlot operator, we used an ex-

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tremely "coarse" screen. Many feedlots "fall through" the screen with a "yes" answer, indicating that they are potential pollution hazards. Experience shows that, on detailed evaluation, relatively few of these are found to be polluters. In other words, the screening method has a large factor of safety for protecting water quality.

Preliminary evaluation provides a "finer" screen, that is, one which is better able to identify feedlots that are not potential pollution hazards. We included a preliminary evaluation method in the appendices. This method may be useful where programmable calculators are available to field personnel.

## Local Watershed

With the longer evaluation form, which must be filled out by the person making the evaluation rather than the feedlot operator, the first step is to study the animal lot and the area around it to determine the local watershed. A detailed sketch must be made of this watershed.

For this evaluation system, we divided the local watershed into three parts (fig. 1). The first part (Area 1) consists of the animal lot itself. Animal lot in this

context refers to an open lot or a combination of open lots intended for the confined feeding, breeding, raising, or holding of animals. It is specifically designed as a confinement area in which manure may accumulate or where the concentration of animals is such that vegetative cover cannot be maintained within the enclosure. This includes poultry ranges, but it does not include pastures. "Animal area" is equivalent to animal lot. Roof areas of buildings are not included in this part.

The second part (Area 2) refers to tributary areas or the areas from which runoff will drain through the lot or wash across it. This usually includes part of the roof areas of buildings in or adjoining the lot and often includes part of the farmstead. The nonroof portions of the tributary areas may be divided into subareas if there are differences in either soil type or ground cover.

The third part (Area 3) is that portion of the local watershed that contributes runoff to a discharge point but is not included in either the feedlot itself or in the tributary areas. This area is referred to as the adjacent area. That part of Area 3 through which runoff from the feedlot passes before reaching the discharge point is referred to as the buffer area. The buffer-adjacent area may be divided into subareas if there are differences in soil type or ground cover within it.

This discharge point is the point nearest the animal lot at which runoff from the lot becomes channelized and no longer receives effective treatment as it flows over surface vegetation. This discharge point may be a tile inlet, the edge of a drainage ditch or sink hole, or the normal high-water mark of a perennial or intermittent stream, lake, or marsh. It may also be some other point closer to the feedlot at which sheet flow of animal lot runoff ceases; for example, a point where the runoff enters a dry run, a gully, or a large rill. The discharge point can also be the inlet of a grass waterway. However, if the grass waterway is used principally for drainage and treatment of the feedlot runoff, it should be included as part of the buffer area. The discharge point would then be at the outlet of the grass waterway.

## Rainfall

After sketching the local watershed, the next step is to determine the design rainfall for which the feedlot is to be evaluated. The runoff volume calculations used to evaluate feedlots for potential pollution can be based on any given design storm. The design rainfall that we selected for use gives a general measure of frequency that runoff from the lot will be allowed to enter the discharge point.

Federal regulations governing animal lots require

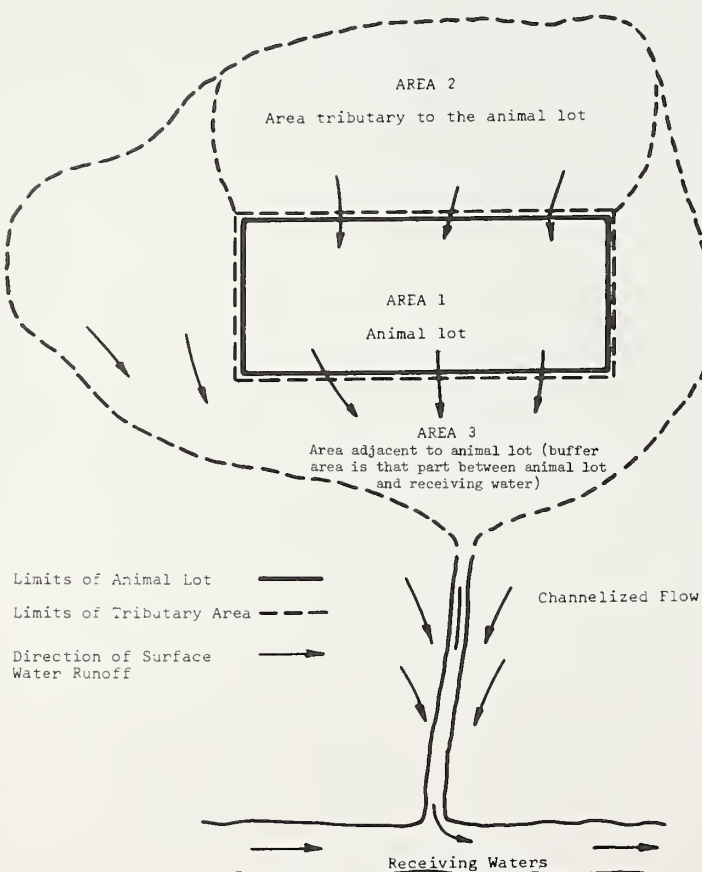


Figure 1. — Local watershed.

that, for animal lots having 1,000 animal units or more, no discharge of surface runoff from the animal lot may occur from a 24-hour duration, one in 25-year frequency rainfall. At the present time, federal regulations do not specify any effluent limitations or performance standards for animal lots having less than 1,000 animal units (43). The Minnesota Code of Agency Rules of the Pollution Control Agency, however, defines as a potential pollution hazard any feedlot or manure storage area whose construction or operation will allow a discharge of pollutants to surface waters of the State in excess of applicable standards during a rainstorm event of less magnitude than a 25-year, 24-hour event.

For this evaluation system, therefore, even though we are dealing mainly with the potential pollution hazards of feedlots with less than 1,000 animal units, we will use as a design storm the 24-hour duration, 25-year frequency rainfall. Rainfall of any other frequency or duration storm easily can be substituted. Figure 1, Appendix B, shows the estimated rainfall for a 25-year, 24-hour rainfall event in the State of Minnesota (42).

The model does not consider pollutants, or nutrients, in precipitation because their contribution would be very small. Measurements of phosphorus in precipitation from several locations in Minnesota indicated that their contribution would probably not exceed 2-1/2 percent of the total phosphorus content of runoff from a vegetated area resulting from a 25-year, 24-hour storm (5, 47).

### Pollutant Indicators

Runoff from feedlots contains many agents that can be considered potential pollutants, including potential disease carrying organisms, other organic material, nutrients, and suspended inorganic solids. These agents affect receiving waters by increasing the nutrient and suspended solid concentration, decreasing the dissolved oxygen content of the water, and in some cases, even threatening human health. For this model, we selected two parameters to represent the potential pollution hazard of feedlot runoff—chemical oxygen demand (COD) and phosphorus (P).

COD is a measure of the amount of oxygen required to oxidize organic and oxidizable inorganic compounds in water and, thus, can be used to indicate the degree of pollution in an effluent; P, an essential element for plant growth, is found in animal manures and mineral deposits and is a major contributor to eutrophication of surface waters. Sufficient data exist on both to develop some general predictive relationships. While feedlots are a source of nitrogen, a potential pol-

lutant of surface waters as well as ground waters, serious difficulties arise in predicting the movement of nitrogen from feedlot surfaces.

COD alone is used for the simplified rating of potential pollution hazard from feedlots because it is a lumped parameter that reasonably appears to be representative of most of the potential pollutants in feedlot runoff. The more detailed information on COD and P is used to design corrective measures and to provide a basis by which the regulatory agency can make judgments on the need for monitoring as well as for pollution-abatement measures.

When dealing with animal wastes, we find that biochemical oxygen demand (BOD) is perhaps a more meaningful parameter than COD, but the analysis for BOD is more complex and time consuming and, as a result, less data are available on BOD concentrations in feedlot runoff. Because animal wastes consist mostly of organic material, however, a number of studies show that, in the case of feedlot runoff, the COD and BOD can be correlated, as can be seen in table 1. These ratios have an average value of 4.57 with a standard deviation of 1.15. Although the ratio will depend on the type of feeding operation and the ration fed for feedlots in the Northern States, a ratio of COD to BOD of approximately 4.5 to 1 appears to be typical and was chosen for use in the model.

### Runoff

We used the soil cover complex method, or curve number method, described in the SCS National Engineering Handbook, Section 4, Hydrology, and illustrated in figure 1, Appendix E, to estimate runoff from rainfall for each of the areas included in the local watershed (39). For this evaluation, we assumed the curve number method to be accurate. Other more sophisticated runoff models are available, but they would add undue complexity to this procedure.

**TABLE 1.—COD/BOD ratios correlated in feedlot runoff**

Source	COD/BOD
Wienecke and others (45) <sup>1</sup> . . . . .	4.66
Agricultural Research Council (1) . . . . .	5.31
Midwest Plan Service (27) . . . . .	4.15
Loehr (19) . . . . .	3.20
Madden and Dornbush (23, 24) . . . . .	4.57
Loehr and others (poultry) (20) . . . . .	6.60
Witzel and others (46) . . . . .	3.50

<sup>1</sup>Italic numbers in parentheses refer to Literature Cited, page 10.

In the curve number method, a combination of hydrologic soil group (representing soil) and land use and treatment class (representing vegetative cover) is used to determine the hydrologic soil cover complex. The relationship of the hydrologic soil cover complex to the amount of rainfall that runs off the area is represented by the runoff curve number. These curve numbers, also referred to as soil cover complex numbers, are shown in table 4, Appendix B, which was derived from table 9.1, Section 4, of the National Engineering Handbook (39). The values for paved and unpaved feedlots were obtained from previous research results (28). We estimated values for the grass waterways to be similar to values from pasture in fair condition. The hydrologic soil groups are found in table 5, Appendix B, which we adapted from table 2.1 of the SCS Hydrology Guide for Minnesota (41). When using the model, the soil type involved must be obtained from a soil survey, the SCS, or other source.

### Equivalent Animal Units

Because animal species differ in their relative production of various waste constituents or potential pollutant material, equivalent animal units (EAU) are determined from tables and used as a unit of measure to compare differences in the production of COD and P, the two parameters used in the model to measure a pollution hazard. We used these EAU's to determine the potential loading of each parameter in the feedlot discharge. The amount of each potential pollutant produced on a regular basis by a 1,000-pound beef feeder or slaughter steer is used as a standard. Thus, the amount of pollutant produced by a beef animal is represented by a value of one, with the amount produced by all other animals being relative to that. These factors then reflect both the manure production of the various animal species and the concentration of COD and P in that manure. Values used, as shown in table 6, Appendix B, are derived from the American Society of Agricultural Engineers (ASAE D-384) data and from the Midwest Plan Service (MWPS-18) data (2, 26).

### Animal Unit Density and Percent Manure Pack

The animal unit density (AUD) is equal to the EAU, divided by the area of the feedlot. Because animals differ in the relative proportion of COD and P generated in manure, the values of EAU and AUD for each will be different.

When animal density is high, such as in confined feedlots, almost all of the rainfall and runoff in and from the lot comes in contact with animal wastes before leaving the lot. When animal density is low, however,

some of the runoff may escape contact with manure and thus contain no fecal contamination. In a previous study (36), the percent coverage was calculated for different densities, assuming completely uniform spreading of cattle manure over a feedlot area, which gives the highest estimate of areal coverage over a given time period.

These figures indicated that one beef animal (1,000 lbs) covered approximately 0.001 acres per day with waste material. Assuming a minimum scraping or removal frequency of 10 days, an animal density of 100 head of beef cattle per acre will result in a 100 percent manure pack. Based on this assumption, we assume that the percent manure pack will vary linearly with AUD up to a value of 100, as shown in figure 2. We emphasized that the percent manure pack factor from this figure reflects the total mass of the pollutant as a product of the total manure produced and the pollutant content of that manure.

Where feedlot systems include partially enclosed areas, or are totally enclosed with some outdoor exercise areas, AUD's must be adjusted on the basis of the average percent of time that the animals spend outside.

### Concentration of Runoff at Feedlot Edge

The concentration of various nutrients in runoff from feedlots has been the subject of many different studies (8, 9, 17, 18, 22, 25, 27, 32, 35, 45, 48). The average concentration of COD and BOD in feedlot runoff appears to increase from north to south in the United States, probably because of increasing average annual temperatures.

Considering only values from high animal density feedlots in the northern one-half of the United States, typical COD concentrations in runoff from feedlots from 10 different studies are shown in table 2. They averaged 4,462 mg/l with a standard deviation of

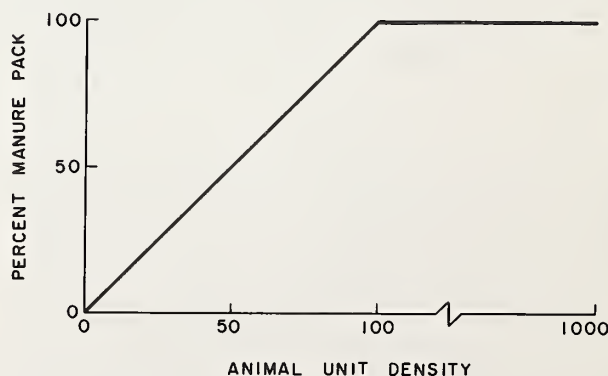


Figure 2. — Percent manure pack versus animal unit density (AUD).

**TABLE 2.—Concentration of COD and P in runoff from feedlots**

Location and source	COD (mg/l)	P (mg/l)
Minnesota (48) <sup>1</sup> . . . . .	4,000	9
Ontario (9) . . . . .	3,441	72
Utah (45) . . . . .	7,265	32
Kansas (25) . . . . .	7,596	79
Nebraska (17) . . . . .	3,529	300
Kansas (8) . . . . .	5,000	50
South Dakota (8) . . . . .	2,160	47
Nebraska (22) . . . . .	3,100	—
Nebraska (35) . . . . .	2,102	374
Kansas (16) . . . . .	6,111	87
Nebraska (18) . . . . .	4,773	30
Ohio (15) . . . . .	—	14

<sup>1</sup>Italic numbers in parentheses refer to Literature Cited, page 10.

1,888 mg/l. While these values vary around the country, depending upon such factors as species or type of feed, based upon this average, a rounded value of 4,500 mg/l was selected as an average concentration of COD in runoff for feedlots having a 100-percent manure pack. A value of 85 mg/l was selected as an average concentration for P. Concentrations were assumed to decrease linearly with percent manure pack below 100 percent as shown in figure 3. The assumption is made here that with AUD's greater than 100, the pollutant concentration of the runoff from the feedlot itself reaches a maximum level and, thereafter, is independent of the number of animal units in the lot.

If a tributary area (Area 2) generates additional runoff volume passing through the feedlot, the concentration of pollutants in this water must also be taken into

consideration. If this volume is small and not channelized, then whatever the pollutant concentration is, as it enters the lot, it will become sufficiently mixed with the runoff water generated within the feedlot to approach the same concentration. If, however, the volume is large, it will not all come in contact with the manure in the lot but will probably channelize as it passes through the lot. In this event, the volume of runoff contributed by Area 2 will have a lower level of concentration of pollutants and will dilute the concentration of the pollutants in the runoff originating in the lot. We estimated this volume at which some dilution will begin to occur as 30 acre-in.

While the background level of pollutants in runoff from tributary areas will depend on the land use in those areas (table 3), for simplification we used a standard background concentration of 60 mg/l of COD and 2 mg/l of P in runoff water in the model.

Concentration of runoff at the feedlot edge is determined using the general relationship:

$$C_1V_1 + C_2V_2 = C_FV_F \quad [1]$$

where  $C_1$  = concentration of runoff in the feedlot, mg/l,  
 $V_1$  = volume of runoff from the feedlot itself, acre-in,  
 $C_2$  = concentration of runoff from Area 2, mg/l,  
 $V_2$  = volume of runoff from Area 2, acre-in,  
 $C_F$  = concentration of runoff at the feedlot edge, mg/l,  
and  $V_F$  = volume of runoff at the feedlot edge, acre-in,

Using the assumed background levels, if the volume from tributary Area 2 is less than or equal to 30 acre-in, the concentration at the feedlot edge is calculated by

**TABLE 3.—Background concentrations of P and COD from various sources**

Source	P (mg/l)	COD (mg/l)
Native prairie (38) <sup>1</sup> . . . . .	0.2	49
Corn (47) . . . . .	.9	
Continuous corn (5) . . . . .	1.1	
Native grass (10) . . . . .	.1	31
Wheat (31) . . . . .	1.4	
Pasture (31) . . . . .	1.0	
Alfalfa (31) . . . . .	2.1	
Corn <sup>2</sup> . . . . .	.3	
Soybeans <sup>2</sup> . . . . .	.5	
Small grain <sup>2</sup> . . . . .	.6	
Cropped watershed <sup>2</sup> . . . . .	.7	59
Road ditches draining cropped land <sup>2</sup> . . . . .		144
Forest <sup>2</sup> . . . . .	.2	78
Soybeans (21) . . . . .	1.5	

<sup>1</sup>Italic numbers in parentheses refer to Literature Cited, page 10.

<sup>2</sup>Young, Robert A. Unpublished data, Morris, Minn.

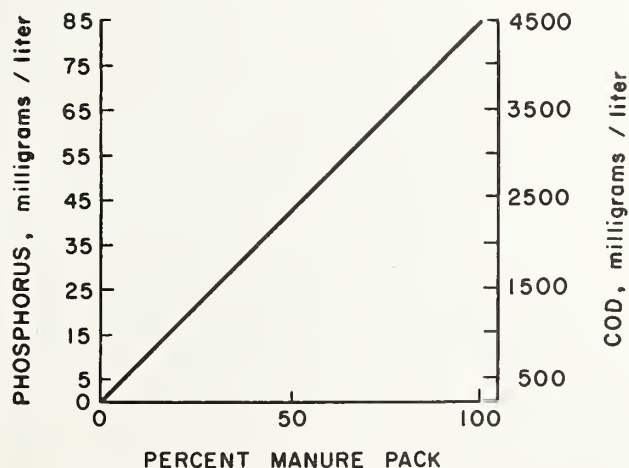


Figure 3.—Concentration of COD and P in feedlot runoff versus percent manure pack.

$$\frac{\text{Percent manure pack}}{100} \times 4500 = \text{mg/l of COD}, \quad [2]$$

$$\frac{\text{Percent manure pack}}{100} \times 85.0 = \text{mg/l of P}. \quad [3]$$

If the volume of runoff from tributary Area 2 is greater than 30 acre-in, the concentration at the feedlot edge is calculated by

$$[\text{percent manure pack} \times 45 \times (V_1 + 30) + 60(V_2 - 30)] / (V_1 + V_2) = \text{mg/l of COD}$$

$$[\text{percent manure pack} \times 0.85 \times (V_1 + 30) + 2(V_2 - 30)] / (V_1 + V_2) = \text{mg/l of P}.$$

where all runoff volumes are expressed in acre-in.

Once the concentration of pollutants at the lot edge is determined, then the mass load of pollutants at the lot edge, in pounds, is simply the concentration of the runoff multiplied by the total runoff leaving the lot.

### Contact Time

As runoff flows overland across vegetated areas or buffer strips, infiltration, filtration, settling, and adsorption of pollutants all decrease the concentration of pollutants in the runoff water. The rate of reduction in concentration of these pollutants depends on the type of vegetation present in the buffer strip and the length of time the water is in contact with this vegetation. Contact time ( $T_c$ ) will depend on the effective length of buffer and the velocity of the runoff water, which is a function of land slope and surface roughness resulting from the type of vegetation present. Runoff velocities for various types of vegetation and different slopes are shown in figure 2, Appendix E (from ch. 15 of SCS National Engineering Handbook, Section 4, Hydrology (39)). For computing purposes, the following equation may also be used to calculate velocity:

$$\log v = 0.5 \log s - c \quad [6]$$

where  $v$  = flow velocity in ft/sec,  
 $s$  = slope in percent,  
and  $c$  = a surface condition constant.

Values of  $c$  are shown in table 2, Appendix B, and were calculated from figure 2, Appendix E. However, since flow velocities greater than 2 ft/sec seldom occur in nature for areas of overland flow, if the buffer area is other than a grass waterway, and the calculated value of velocity is greater than 2 ft/sec, a maximum value of 2 should be used. Figure 2, Appendix E, was derived by assuming Manning's flow equation for channels was valid for overland flow (6).

The  $c$  value of "1" shown for grass waterways in table 4, Appendix B, is used only as a flag in the calculator program to indicate a different series of calculations.

When manually calculating runoff velocity in grass waterways using equation [6], the  $c$  value that should be used is -0.18. This value was determined from velocity curves for low retardance channels ( $n = 0.04$ ) (6).

Once runoff velocity has been estimated,  $T_c$  is calculated by dividing the distance ( $L$ ) from the feedlot edge to the discharge point by the runoff velocity ( $v$ ):

$$T_c = L/v \quad [7]$$

### Pollutant Reduction from Filtration

Based on several studies, vegetative buffer areas are a relatively effective means of reducing the concentration of potential pollutants from runoff waters (3, 12, 13, 30, 37, 44, 48). Based on measured data from these studies, we developed the following equations by simple regression analysis to estimate the percent reduction in pollutant strength of feedlot runoff moving as overland flow as it passes through a vegetative buffer area:

$$D_{c1} = -27.9 + 42.8 \log T_c \quad [8]$$

$$D_{p1} = -49.3 + 50.5 \log T_c \quad [9]$$

where  $D_{c1}$  = percent reduction in COD concentration  
(if  $< 0$ ,  $D_{c1} = 0$ ),

$D_{p1}$  = percent reduction in P concentration

(if  $< 0$ ,  $D_{p1} = 0$ ),

and

$T_c$  = contact time in sec.

Equations [8] and [9] do not apply to grass waterways. Channelized flow is not as effective as overland flow in removing potential pollutants (11, 44). They require a much greater flow length, or contact time, to achieve the same level of removal as an area of overland flow. For this reason, we developed the following equations for grass waterways as buffer areas (11, 14):<sup>4</sup>

$$D_{c2} = 15.95 + 0.033 T_c \quad [10]$$

$$D_{p2} = 21.2 + 0.036 T_c \quad [11]$$

where  $D_{c2}$  = percent reduction in COD concentration  
in a grass waterway (if  $< 0$ ,  $D_{c2} = 0$ ),

$D_{p2}$  = percent reduction in P concentration  
in a grass waterway (if  $< 0$ ,  $D_{p2} = 0$ ),

and  $T_c$  = contact time in sec.

Both sets of equations are illustrated in figures 3 and 4, Appendix E. If the buffer area consists of portions of both overland flow and grass waterway, the net reduction in concentration is calculated by

$$C_F \times \left(1 - \frac{D_1}{100}\right) \times \left(1 - \frac{D_2}{100}\right) = C_R \quad [12]$$

<sup>4</sup>Swanson, N. P., Mielke, L. N., and Ellis, J. R. Control of feedlot runoff with a waterway. Unpublished report.

where  $C_F$  = pollutant concentration at the feedlot edge,  
 $D_1$  = percent reduction in pollutant concentration  
in overland flow,  
 $D_2$  = percent reduction in pollutant concentration  
in grass waterway,

and  $C_R$  = reduced pollutant concentration.

If the calculated net reduction equals or exceeds 100 percent, then the buffer strip is sufficient to eliminate any potential pollution hazard posed by the feedlot.

### Concentration Reduction from Dilution

In addition to a reduction in pollutant strength from the nature of the vegetated buffer area, a further change in concentration occurs as a result of dilution of the feedlot runoff with the relatively cleaner water running off from the adjacent areas. This change can be calculated by using the following equation:

$C_R V_F + C_3 V_3 = C_T V_T$   
where  $C_R$  = reduced concentration after filtration, mg/l,  
 $V_F$  = runoff volume at the feedlot edge, acre-in,  
 $C_3$  = concentration of runoff from Area 3, mg/l,  
 $V_3$  = runoff volume from Area 3, acre-in,  
 $C_T$  = final concentration at the discharge point, mg/l,  
and  $V_T$  = total runoff volume at the discharge point, acre-in.

As with runoff from the tributary areas of the feedlot, background levels of COD and P of runoff generated by the buffer area and other adjacent areas are assumed to be 60 mg/l and 2 mg/l, respectively. The product of final concentration times the total runoff volume for the feedlot watershed system is equal to the mass load of pollutants, in pounds, reaching the discharge point.

### Determining Whether Pollution Hazard Exists

Once the final concentration of the runoff at the discharge point is estimated, you must determine whether it is a pollution hazard. If it is, then the feedlot can be rated on the basis of its potential to pollute a receiving body of water. We chose COD as the critical parameter on which to judge severity of the potential pollution hazard posed in the feedlot.

The final COD concentration of the runoff at the discharge point is compared with the limits that the State has set for allowable concentrations of COD in all waters of the State. For Minnesota, these limits are set forth in chapters 14 and 15 of the Water Pollution Control Regulations, promulgated in 1973, which state that the limiting concentration for 5-day BOD is 25 mg/l (29).

As previously stated, for feedlots in the Northern States, the ratio of COD to BOD is approximately 4.5 to 1. Therefore, a limiting COD concentration of 112 mg/l is approximately equivalent to the limiting BOD

concentration of 25 mg/l and is used for comparison with the calculated final concentration of COD in the runoff to determine if the feedlot poses a potential hazard. If the calculated COD exceeds 112 mg/l, the lot is assumed to be a potential hazard and is subjected to a numerical rating procedure. Any other limiting concentration of COD or P could be easily substituted at this point if desired.

### Feedlot Rating

The feedlot rating is based only upon the mass load, in pounds of COD, contributed by the feedlot itself and does not include any additional background COD loading contributed by tributary areas above the feedlot or adjacent areas. However, we subtracted any attenuation in loading caused by runoff passing through the buffer from the total at the feedlot edge. The remaining load, in pounds, is first used to determine a factor,  $F_1$ , which compresses the range of possible loads onto a logarithmic scale from zero to about 1, as follows:

$$F_1 = \frac{(\log \text{COD}_{\text{mass load}}) - 2}{3} \quad [14]$$

A second factor,  $F_2$ , is then calculated to slightly modify or weight  $F_1$  on the likelihood of a significant runoff event occurring for that feedlot, considering the location of that feedlot in the State and the ability of its local watershed to intercept and hold runoff. This weighting follows the form:

$$F_2 = 0.8 + 0.1 \log (V_T) \quad [15]$$

where  $V_T$  = total volume of runoff from the local watershed in acre-in for the design storm.

The product of  $F_1$  and  $F_2$ , multiplied by 100 and rounded off to the nearest whole number, is equal to the animal lot rating. This numerical rating places a value from zero to approximately 100 on all feedlots whose mass COD load in pounds at the receiving water is from 100 to 100,000 lb and can now be used to assess the relative potential pollution hazard posed by any of the approximately 90,000 feedlots in the State. This rating is **not** a percentile. Estimates show that more than one half of all polluting feedlots in the state would be rated between 40 and 70.

### Combining Feedlot Ratings

If the runoff from one or more animal lots at one location does not mix within a single local watershed, animal lot evaluations should be done separately for each feedlot watershed. The ratings of each can then be combined, either manually or using a short computer program, to get a net rating for the system. The computer program for this procedure is found in Appendix D.

## Limitations

This feedlot evaluation system has a number of limitations:

(1) The calculations used in determining the concentrations and mass loads of pollutants are based upon the most current research data available but use average values only. Therefore, results and figures are estimates and are not to be regarded as absolute values. Their main purpose is to provide a uniform basis for comparison between feedlots regardless of their location in the State.

(2) If the tributary areas above the feedlot or the adjacent areas below the feedlot are very large, that is, greater than 100 acres, then the runoff calculations become somewhat questionable because of the greater chance for error in determining cover and topographic conditions. Also, the curve number method, upon which all of the runoff calculations are based, was developed primarily from runoff data from relatively small watersheds. Of the approximately 70 watersheds used in developing the curve number system, at least 50 were less than 100 acres (7).

In checking the accuracy of the curve number method, using observed versus estimated values of runoff from 25 small, single-crop watersheds (34), we obtained the following regression equation:

$$Q_{\text{est}} = 1.365 + 0.578 Q_{\text{obs}} \quad [16]$$
$$r^2 = 0.616$$

where  $Q_{\text{est}}$  = estimated average annual direct runoff,

$Q_{\text{obs}}$  = observed average annual runoff,

and  $r^2$  = coefficient of variation.

This equation indicates that the method underestimates runoff of more than 3-1/4 in while overestimating runoff of less than 3-1/4 in.

(3) The evaluation system gives an indication of the quality of runoff only at the feedlot edge and the defined discharge point; the rating indicates the impact of the discharge on the receiving water at the discharge point. The system does not deal with the value or importance of the receiving water, nor does the rating reflect this factor. The user of the system—county Agricultural Stabilization Conservation Service committee, pollution control official, or others—shall assess the value of the receiving water. This is a local determination and can best be performed by persons familiar with their local waters.

(4) The definition of discharge point, as described earlier, is sometimes difficult to apply in the field (Appendix F).

(5) The potential pollution threat to ground water is treated only lightly in this system. Since ground-water pollution is a matter of serious concern in Minnesota, it deserves additional discussion at this point.

The pollution hazard to ground water has been touched on only superficially in the model because of the difficulty of analyzing the many factors affecting it and because those factors are less subject to generalization than are the factors affecting surface waters. Persons using this system to evaluate feedlots for potential pollution problems, however, should be aware of some considerations that could lead to ground-water pollution, even though their degree of seriousness can only be estimated subjectively, unless an extensive program of site-specific studies is undertaken.

Some significant factors to consider in potential ground-water pollution are the depth to the water table or bedrock, the distance to the nearest well, soil characteristics, the local watershed topography, and the type of vegetation present in the area.

As water passes through the soil profile, many potential contaminants are removed or transformed either by plant roots, soil microorganisms, or other natural processes. Therefore, the farther water must pass through the soil before reaching ground water, the less chance of polluting the ground water. Depth to the water table or bedrock, therefore, plays an obvious role in the potential pollution of ground water. The distance to the nearest well also can be significant in considering potential ground-water pollution because the closer a water well is to a source of pollution, the higher the chance for contaminating that well.

Most of those soil characteristics relating to potential ground-water pollution generally are reflected in the hydrologic soil group. The hydrologic soil group is a classification characterizing the natural drainage of a soil and has values ranging from A to D. Group A is a well-drained soil having high infiltration rates, whereas Group D is a poorly drained soil with very slow infiltration rates under wet conditions. This system of classifying soils takes into consideration soil structure and soil texture and their effects on infiltration, permeability, and hydraulic conductivity. Soils belonging to Group A have a low potential for surface-water pollution but may pose a fairly severe hazard to ground water because of their drainage characteristics, which allow more water to infiltrate and percolate downward. Conversely, while soils of hydrologic Group D may pose a severe hazard to surface-water pollution, their potential for polluting ground water is less because relatively little water infiltrates into the soil. The model considers the effect of the hydrologic soil group on the estimated pollutant load to surface waters only.

Another soil factor, which may play a significant role in affecting the potential for ground-water pollution, is the soil cation exchange capacity (CEC). CEC, simply

stated, is the ability of soil colloids to adsorb and store positively charged ions on their surface. Since adsorbed ions are less likely to be leached to ground water, soils having a low CEC will pose a much greater threat to ground water than those having a high CEC. CEC depends primarily on soil texture and organic matter content, but it is also affected by clay type and soil pH. Generally, the finer the soil texture or the greater the organic matter content, or both, the higher the CEC. CEC is measured in millequivalents per 100 g of dry soil and can be estimated by using this equation (4):

$$\text{CEC} = (2 \times \text{pct. organic matter}) + (0.5 \times \text{pct. clay}). \quad [17]$$

The topography of a watershed, both macro and micro, affects the pollution potential to ground water because of its effect on the rate at which water is conducted across the watershed to the outlet. The faster the runoff moves across the surface, the less time for infiltration. Macrotopography refers to the land slopes within the watershed. The steeper the slopes, the more rapidly the runoff water is conducted across the watershed, thus allowing less infiltration. Microtopography refers mainly to the soil surface condition or roughness. A rough cloddy surface will decrease runoff and increase the potential for infiltration and ground-water pollution compared to a smooth-tilled surface.

Many practices such as till planting, ridging, contour stripping and terracing, while helping to control soil loss and runoff may, as a result, actually increase the potential for ground-water pollution. The general effects of most of these systems on surface-water pollution are considered in the model in the curve number method of calculating estimated runoff. As with a hydrologic soil group, however, where conditions are beneficial to reducing potential surface-water pollution, generally they will increase the potential for ground-water pollution.

The type of vegetation present downslope from a

feedlot is also an important consideration in assessing potential ground-water pollution hazard. As stated in the discussion of surface-water pollution, vegetation affects runoff by increasing the infiltration, filtration, settling, and adsorption of pollutants, all of which reduce the concentration of pollutants in runoff water. These same actions will tend to reduce the potential for ground-water pollution with the possible exception of increasing infiltration. More water infiltrating into the soil can increase the possibility of contaminants reaching the ground water. However, plants take up different amounts of nutrients and different proportions of nutrients from a soil according to their species and to soil conditions (33).

Nitrates are the major potential soluble ground-water contaminants. If the vegetation through which the runoff passes has a high capacity for utilizing nitrogen, much of the nitrate in the infiltrating water may be extracted by the plant roots, lessening the chance of nitrate contamination reaching the ground water, thus offsetting any increased infiltration. If a crop is to be planted with the specific purpose of serving as a vegetative filter for feedlot runoff, then such crops as corn, soybeans, or alfalfa, with high-nitrogen requirements, would probably be more suitable for use than crops with lower nitrogen requirements.

A final consideration in potential ground-water pollution is the sink-hole potential. The southeast corner of the State of Minnesota includes a large area of Karst topography, that is, an area of porous limestone containing deep fissures and sink holes and characterized by many underground caves and streams. Feedlot runoff in these areas can provide a severe threat to ground-water quality. As yet, there are no proven means for objectively assessing the seriousness of the problem in the Karst areas. The severity of the threat to ground-water pollution must be subjectively evaluated on a case-by-case basis.

## Summary

In conclusion, the evaluation system described in this report was developed through the cooperation of several State and Federal agencies to provide a uniform and objective method of evaluating and rating the pollution potential of the approximately 90,000 animal feedlot operations in the State of Minnesota. The system is simple to use and appears to be quite precise. It

provides a generally equitable means of dispersing public funds for pollution abatement, based on the severity of the hazard posed by any feedlot operation relative to that of any others. It also helps persons designing feedlot improvements to find the most economical and practical way to abate surface water pollution from any feedlot.

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## Appendix A

### Feedlot Screening Procedure

The screening procedure is based on the premise that if no allowance is made for dilution with water carrying a low background level of chemical oxygen demand (COD), that is, runoff from Area 2, then the maximum allowable COD concentration in the feedlot runoff is 112 mg/l. Based on the COD or percent manure pack relationship shown in figure 3 (text p. 5), this concentration is equivalent to the COD concentration generated by a feedlot having an animal unit density (AUD) of 2.5 animal units per acre ( $2.5 \times 45 \text{ mg/l} = 112.5$ ). Therefore, if the distance from the feedlot edge to the discharge point is sufficient to reduce the COD concentration in the runoff to the level that would result from a feedlot having an AUD of 2.5, then the lot would not present a threat to water quality. The screening procedure uses the relationship between contact time ( $T_c$ ) and percent COD reduction (equation [8], p. 6) to determine this.

The screening formula may be derived as follows:

Given: feedlot area, A  
distance from feedlot to discharge point, L  
animal type, number, and COD factor,  

$$\text{EAU} = \Sigma \text{ number of animals} \times \text{COD factor}$$
(for all animal types)  

$$\text{AUD} = \text{EAU}/A$$
  
Percent reduction =  $D_c = -27.9 + 42.8 \log T_c =$   

$$100 \left( \frac{\text{AUD} - 2.5}{\text{AUD}} \right)$$
  
or 
$$42.8 \log T_c \geq 127.9 - \frac{250}{\text{AUD}}$$
  
where 
$$T_c = L/v$$
  
where 
$$v \leq 2 \text{ ft/sec.}$$
  
For the worst case  $v=2$  and  $L = 2T_c$ ,  
then 
$$\log L = \log 2 + \log T_c.$$
  
Thus, 
$$\log L = \log 2 + 2.99 -$$
  

$$\frac{5.84}{\text{AUD}} = 3.29 - \frac{5.84}{\text{AUD}},$$
  
and 
$$L = 10^{(3.29 - \frac{5.84}{\text{AUD}})}$$
  
(If AUD > 100, use 100).

This is the screening formula, and it is used to calculate the minimum value of L that would be required before the feedlot would be considered to pose no pollution

hazard. If L, as calculated above, is greater than the value of L reported on the screening form, then the feedlot could present a hazard and should be evaluated further.

Field experience has pointed out the need for a more sensitive screening tool. A preliminary evaluation method, based on a detailed evaluation of the buffer, is presented here to meet this need. This preliminary evaluation can be further refined with certain information from the screening form. It should be noted that this supplementary method is optional and has not been implemented in Minnesota.

The preliminary evaluation must be conducted on the site by the technician. It will result in time savings only if the technician is equipped with a portable programmable calculator so that the preliminary evaluation can be determined immediately at the conclusion of a brief field inspection. If the feedlot is then determined to be a potential pollution hazard, the technician immediately can continue to examine the feedlot and collect the additional data needed for a full evaluation. Instructions for Hewlett-Packard calculators, therefore, are incorporated in the preliminary evaluation form.

The preliminary evaluation formula is based on most of the same assumptions as the screening formula. It is derived simply by substituting the actual  $T_c$ , calculated for the buffer in existence on the property, for the estimated  $T_c$  ( $T_c = L/2$ ).

$$\text{Thus} \quad 42.8 \log T_c = 127.9 - \frac{250}{\text{AUD}}$$

$$\text{and} \quad \log T_c = 2.988 - \frac{5.841}{\text{AUD}}$$

In the worst case, AUD = 100, so the required  $T_c = 851$  sec. The preliminary evaluation first checks the calculated  $T_c$  using this worst case AUD; if  $T_c$  is insufficient, the feedlot is a potential hazard. If the technician believes the AUD is less than 100, information needed for calculating AUD is input, and the actual  $T_c$  (from buffer calculations) is compared to the required  $T_c$  (from equation above).

If  $T_c$  is insufficient—either with or without detailed information on AUD—the feedlot could pose a hazard and should be evaluated further.

## Appendix B

### Feedlot Evaluation System—Feedlot Screening

Applicant \_\_\_\_\_ Location \_\_\_\_\_  
(Section, Township, County)

**A. Screening for surface-water pollution hazard:**

- (1) What are the approximate dimensions, or what is the approximate area of the animal lot?

\_\_\_\_\_ ft X \_\_\_\_\_ ft or \_\_\_\_\_ acres

- (2) Approximately how far away from the animal lot is the nearest point where sheet flow ceases or flow becomes channelized? This may be a tile inlet, the edge of a gully, drainage ditch or sink hole, the inlet of a grass waterway or the normal high-water mark of a perennial or intermittent stream, lake, or marsh. \_\_\_\_\_ ft

- (3) What types of animals is the lot intended to support, and what is the maximum number of each? If more than three types, write in margin.

Animal Type	Number of animals	
_____	_____	_____
	COD factor	_____
_____	Number of animals	_____
	COD factor	_____
_____	Number of animals	_____
	COD factor	_____

- (4) Screening result from programmable calculator  
(zero = no hazard, two = evaluation needed) \_\_\_\_\_

Calculated by (clerk's  
initials and date) \_\_\_\_\_

CONTINUE AND COMPLETE ON NEXT PAGE:

**TABLE 1.—Ratio of COD produced by various  
animals to  
that produced by a 1,000 pound slaughter steer**

Animal type	Design weight <sup>1</sup>	COD
	<i>Pounds</i>	
Slaughter steer .....	1,000	1.00
Young beef .....	500	.50
Dairy cow .....	1,400	1.96
Young dairy stock .....	500	.70
Swine .....	200	.17
Feeder pig .....	50	.04
Sheep .....	100	.18
Turkey .....	10	.02
Chicken .....	4	.01
Duck .....	4	.01
Horse .....	1,000	.42

<sup>1</sup>Interpolation of values should be based on the maximum weight that the animal would be expected to reach.

B. Screening for ground-water pollution hazard:

(1) How would you describe the soils around your feedlot?

☐ light

☐ medium

☐ heavy

(2) Estimate the depth to ground water or bedrock: \_\_\_\_\_ ft.

(3) Is further evaluation of ground-water pollution potential needed?

Clerk's initials  
and date: \_\_\_\_\_

☐ yes  
☐ no

I have received a summary of how the cost-share programs apply to feedlots. I understand that the pollution potential of my feedlot must be evaluated to help set priorities for cost sharing. To assist in the evaluation, I have provided the above information, which is correct to the best of my knowledge.

Signed \_\_\_\_\_  
(Applicant)

Date \_\_\_\_\_

Screening instructions

For surface-water pollution hazard -

1. Determine acreage of feedlot from dimensions, if necessary.
2. For each animal type in question 3, insert the appropriate COD factor from Table 1.
3. Calculate the screening using the H-P or Monroe/Compucorp programmable calculator.
4. The screening program will display and print either a zero or a two.
  - If zero, the animal lot is not a potential surface-water pollution hazard, and no further evaluation is necessary.
  - If two, the animal lot may be a potential surface-water pollution hazard. It should be evaluated using the Evaluation Data Form and calculated starting with program #2 on either programmable calculator.

For ground-water pollution hazard -

Further evaluation of the ground-water pollution potential is needed if -

soils are described as:	depth to ground water or bedrock is less than:
light	and 6 feet
or medium	and 4 feet
or heavy	and 2 feet

## Feedlot Evaluation System—Preliminary Evaluation Data

Operator \_\_\_\_\_ Location \_\_\_\_\_  
(Section, Township, County)

This is a preliminary evaluation of the potential surface-water pollution hazard of runoff from an open animal lot.

Definitions, as used in this preliminary evaluation, are as follows:

Buffer -- That area of land where surface runoff from the lot receives effective treatment as it flows over vegetation, not including any grass waterway. The total length of the buffer is the shortest distance, measured along the line of flow, from any part of the lot to the discharge point.

Discharge Point -- The point where runoff from the lot and the buffer becomes channelized and no longer receives effective treatment as it flows over surface vegetation. The discharge point may be a tile inlet; the edge of a sinkhole, drainage ditch, or grass waterway; the normal high-water mark of a perennial or intermittent stream, lake, or marsh if animal lot runoff drains to such an area; or the point where the runoff enters a dry run, gully, or large rill.

### First-level preliminary evaluation

Divide the buffer into one or more sections so that each is fairly uniform in both ground cover and slope. If there is no buffer, proceed with a complete animal lot evaluation.

Survey the slope of each section. If slope is surveyed as zero, record as .01. Refer to table 2 for the surface condition constant c.

	Slope (S)	= _____	Percent
Ground cover _____	(c)	= _____	
	Distance (L)	= _____	
	Slope (S)	= _____	Percent
Ground cover _____	(c)	= _____	
	Distance (L)	= _____	

**TABLE 2. — Surface condition constant for various types of cover**

Ground cover	Surface condition constant (c)
Fallow .....	0.22
Row crops:	
Straight rows .....	.05
Contoured rows .....	.29
Rotation meadow, small grains, legumes, or woodland .....	.29
Farmsteads .....	.01
Forest with heavy litter, permanent meadow .....	.59
Pasture: <sup>1</sup>	
Poor .....	.01
Fair .....	.15
Good .....	.22

<sup>1</sup>Pasture should be considered "poor" if it is heavily grazed, with no mulch. "Fair" pasture has between 50 and 75 percent plant cover and is moderately grazed. "Good" pasture is lightly grazed and has more than 75 percent plant cover.

Calculate preliminary evaluation on the Hewlett-Packard 67/97.

- (1) Turn power switch to "on", set man-trace-norm switch on "norm" and prgm-run switch on "run", and insert program card 6 into calculator (side 1 only). (Feed printed side up.)
- (2) Press "A". After flickering briefly, the display will read "6.00".
- (3) Enter data on ground cover and slope from previous page. After each complete number entry, press "R/S".
  - CAUTION: Do not depress any key while display is flickering.
  - Note that the spacing of the printed tape matches the format of this form.
  - While only two sets of blanks are provided, note that any number of buffer sections may be entered.
  - When information for all buffer sections has been entered, the display will show "0.00". Press "R/S" to enter the zero from the display, signaling the calculator that there are no additional buffer sections.

- (4) After the display flickers briefly, the calculator will display and print "0.00" or "2.00".

- If "0.00", the lot is not a potential surface-water pollution hazard. The preliminary evaluation is complete.
- If "2.00", further information is required to determine whether the lot may be a potential surface-water pollution hazard. Continue with the second level.

### Second-level preliminary evaluation

Determine and enter the area of the lot in either of these two ways:

Use the calculator to compute the area of the lot in square feet. When the correct number of square feet shows in the display, press "C" to automatically convert the area to acres; continue with the next step.

Determine the area of the lot:

\_\_\_\_\_ acres

Key this number into the calculator, press "R/S", and continue with the next step.

Enter the number of animals in the lot and the animal-type factor from Table 3 for chemical oxygen demand (COD) as follows:

Animal type

_____	Number of animals	= _____
_____	COD factor	= _____
_____	Number of animals	= _____
_____	COD factor	= _____
_____	Number of animals	= _____
_____	COD factor	= _____

**TABLE 3. — Ratio of COD produced by various animals to that produced by a 1,000 pound slaughter steer**

Animal type	Design weight <sup>1</sup>	COD
	<i>Pounds</i>	
Slaughter steer .....	1,000	1.00
Young beef .....	500	.50
Dairy cow .....	1,400	1.96
Young dairy stock .....	500	.70
Swine .....	200	.17
Feeder pig .....	50	.04
Sheep .....	100	.18
Turkey .....	10	.02
Chicken .....	4	.01
Duck .....	4	.01
Horse .....	1,000	.42

<sup>1</sup>Interpolation of values should be based on the maximum weight that the animal would be expected to reach.

Enter the animal data into the calculator.

- While only three sets of blanks are provided, note that any number of animal types may be entered.
- When information for all animal types has been entered, the display will show "0.00". Press "R/S" to enter the zero from the display, signaling the calculator that there are no additional animal types.

After the display flickers briefly, the calculator will display and print "0.00" or "2.00".

- If "0.00", the lot is not a potential surface-water pollution hazard. The evaluation is complete.
- If "2.00", the lot may be a potential surface-water pollution hazard. Proceed with a complete animal lot evaluation.

**NOTE:** If an error in entering data is made at any point, it is not necessary to reenter card 6. Simply press "A", and proceed to enter data for first-level evaluation after the display reads "6.00". Similarly, to check your work or to conduct a preliminary evaluation of another animal lot, simply press "A" and proceed to enter data.

Feedlot Evaluation System—Animal Lot Evaluation Data

Operator \_\_\_\_\_ Location \_\_\_\_\_  
(Section, Township, County)

This is a system for evaluating the potential pollution hazard of runoff from an open animal lot. It provides numerical ratings for both the surface-water pollution hazard and the ground-water pollution hazard.

Definitions, as used in this system:

- Animal lot -- an open lot, or a combination of open lots, intended for the confined feeding, breeding, raising, or holding of animals and specifically designed as a confinement area in which manure may accumulate, or where the concentration of animals is such that a vegetative cover cannot be maintained within the enclosure. This includes poultry ranges, but does not include pastures. "Animal area" is equivalent to "animal lot".
- Area 1 -- The animal lot or lots, less any area covered by a roof. (Roof area is considered part of Area 2 if it drains across the lot. Otherwise, it may be part of Area 3 or outside the local watershed entirely.)
- Area 2 -- Area tributary to the animal lot, that is, the area from which runoff will drain through the lot or wash across it. Usually includes part of the roof area of buildings adjoining the lot and often includes part of the farmstead.
- Area 3 -- That part of the local watershed that contributes runoff to the discharge point but is not included in Area 1 or Area 2. Area 3 includes the entire buffer, plus any other area whose runoff flows over the buffer.
- Buffer -- That part of Area 3 in which runoff from the animal lot receives effective treatment as it flows over surface vegetation.
- Discharge Point -- The point where runoff from the local watershed becomes channelized and no longer receives effective treatment as it flows over surface vegetation. The discharge point may be a tile inlet, the edge of a sinkhole, drainage ditch or grass waterway,\* or the normal high-water mark of a perennial or intermittent stream, lake, or marsh, if animal lot runoff drains to such a point. The discharge point may also be some other point, closer to the animal lot, at which sheet flow of animal lot runoff ceases--for example, a point where the runoff enters a dry run, gully, or large rill.
- Local Watershed -- The smallest watershed that includes the animal lot and the buffer. Consists of Areas 1, 2, and 3.
- \* If an animal lot and its associated Area 2 comprise the majority of the drainage area of a grass waterway, and the waterway is designed principally to treat feedlot runoff, the grass waterway constitutes a buffer and its outlet should be considered the discharge point.

## Calculations and notes

Information for Step 4 ( next page):  $43,560 \text{ ft}^2 = 1 \text{ acre}.$

Formulas for calculating areas:

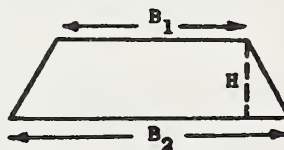
1. Square or Rectangle:  $= L \times W$



2. Triangle:  $= \frac{B \times H}{2}$



3. Trapezoid:  $= \frac{(B_1 + B_2) \times H}{2}$



4. Circle:

a.  $A = \pi R^2$   
or

b.  $A = \frac{\pi D^2}{4}$   
or

c.  $A = 0.785 D^2$



The following steps should be taken to evaluate and rate an animal lot:

### Surface-water pollution potential

Step 1. Carefully study the animal lot and the area immediately surrounding it. Briefly describe the discharge point, using the name of the receiving water, if applicable, in the blank on page 29.

Step 2. On the back of this form, sketch the local watershed. For those portions of this watershed outside the animal lot itself, indicate soil types (use the best available soils information) and ground cover (use the categories in table 4). Determine the outside (plan) dimensions of the roofs of barns, feeders, and other buildings. Scale all land dimensions needed for the sketch, using the best available maps and photos, or pace the distances. If the lot is partly paved and partly earthen, estimate the proportion of the total that is paved.

Indicate Areas 1, 2, and 3 on the sketch. Divide Areas 2 and 3 into sub-areas (2a, 2b, 2r; and 3a, 3b, 3c, 3d) if there are differences in soil types or ground cover or if parts are paved or roofed.

Step 3. Determine the design rainfall (R) from rainfall map (fig. 1) for a 25-yr, 24-hour rainfall.  $R = \underline{\hspace{2cm}}$  in (1)

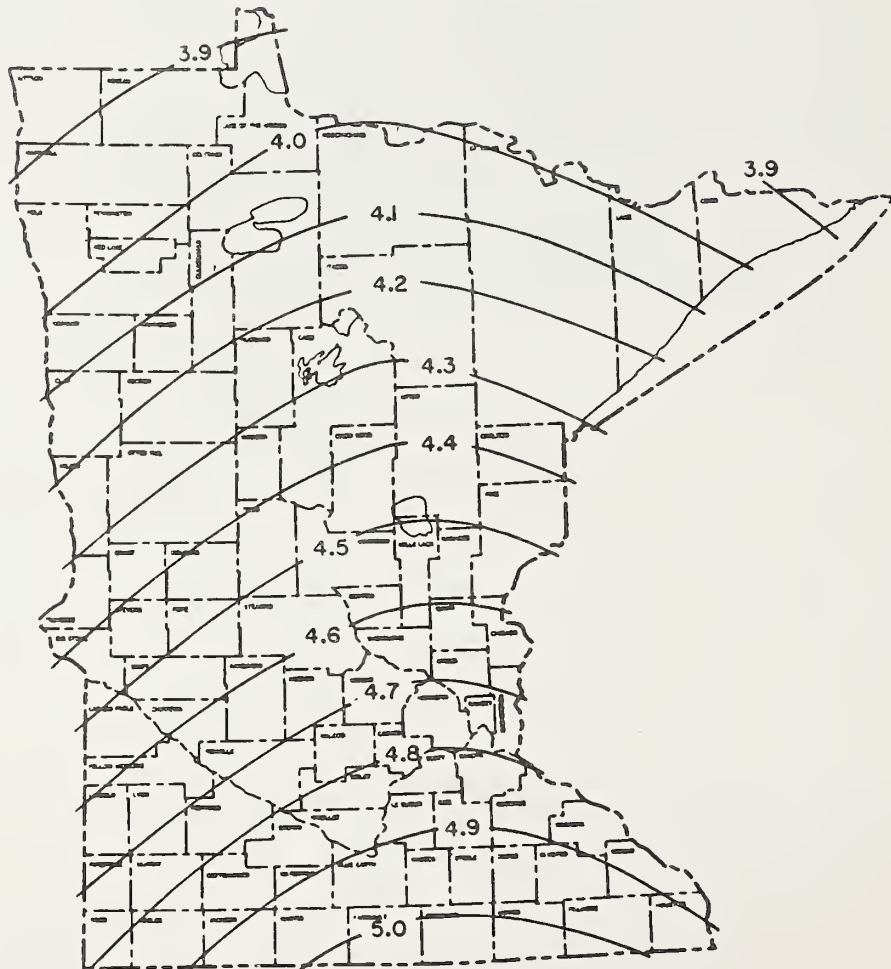
Step 4. Complete all blanks in the following table, inserting "0" in all blanks not otherwise filled. Record the ground cover of each area or sub-area as well as their sizes. (Ground cover was indicated on the sketch.) Sizes may be determined from the dimensions on the sketch or, if sketch is drawn to scale, a planimeter or an SCS transparent area scale may be used.

Area 1 Feedlot	_____ ft. <sup>2</sup>	= _____ acre (2)
Area 2a _____	_____ ft. <sup>2</sup>	= _____ acre (3)
Area 2b _____	_____ ft. <sup>2</sup>	= _____ acre (4)
Area 2r Roof Area	_____ ft. <sup>2</sup>	= _____ acre (5)
Area 3a _____	_____ ft. <sup>2</sup>	= _____ acre (6)
Area 3b _____	_____ ft. <sup>2</sup>	= _____ acre (7)
Area 3c _____	_____ ft. <sup>2</sup>	= _____ acre (8)
Area 3d _____	_____ ft. <sup>2</sup>	= _____ acre (9)

Step 5. Enter soil cover complex number (CN) for the animal lot (Area 1) based on the following table:

Percent paved	0-24	25-49	50-74	75-100
CN	91	92	93	94

CN = \_\_\_\_\_ (10)



SOURCE:USWB TP 40

Figure 1. —25-year, 24-hour rainfall (inches).

**TABLE 4. — Surface condition constant and soil cover complex numbers for various cover conditions**

Cover	Surface constant (c)	Soil cover complex number			
		Soil Group A	Soil Group B	Soil Group C	Soil Group D
Fallow .....	0.22	77	86	91	94
Row crop:					
Straight row .....	.05	67	78	85	89
Contoured .....	.29	65	75	82	86
Small grain .....	.29	63	74	82	85
Legumes or rotation meadow ...	.29	58	72	81	85
Pasture: <sup>1</sup>					
Poor, .....	.01	68	79	86	89
Fair .....	.15	49	69	79	84
Good .....	.22	39	61	74	80
Permanent meadow .....	.59	30	58	71	78
Woodland .....	.29	36	60	73	79
Forest with heavy litter .....	.59	25	55	70	77
Farmsteads .....	.01	59	74	82	86
Grass waterway .....	1.00 <sup>2</sup>	49	69	79	84
Animal lot:					
Unpaved .....				91	
Paved .....				94	
Roof area .....				100	

<sup>1</sup>Pasture should be considered "poor" if it is heavily grazed with no mulch.

"Fair" pasture has between 50% and 75% plant cover and is moderately grazed.

"Good" pasture is lightly grazed and has more than 75% plant cover.

<sup>2</sup>Disregard this value when interpolating c values. The "one" for a grass waterway should not be treated as a number. It is merely a code that tells the calculator to use a special formula for computing buffer effectiveness.

Source: Hydrology Guide for Minnesota, USDA-SCS, St. Paul, MN.

Step 6. Complete all blanks in the following table, inserting "0" in blanks not otherwise filled. Soil type was indicated on the sketch. After determining the soil hydrologic group from table 5, find the soil cover complex number from table 4.

	Soil Type	Soil Hydro- logic Group		
Area 2 <sub>a</sub>	_____	_____	CN = _____	(11)
Area 2 <sub>b</sub>	_____	_____	CN = _____	(12)
Area 2 <sub>r</sub> Roof				
Area 3 <sub>a</sub>	_____	_____	CN = _____	(13)
Area 3 <sub>b</sub>	_____	_____	CN = _____	(14)
Area 3 <sub>c</sub>	_____	_____	CN = _____	(15)
Area 3 <sub>d</sub>	_____	_____	CN = _____	(16)

Step 7. Identify the buffer. If there is no buffer, enter zero on line 17 and continue with Step 8.

The total length of the buffer is the shortest distance, measured along the line of flow, from any part of the animal lot to the discharge point. This length may be analyzed as one or more sections so that each is fairly uniform in both ground cover and slope. Note that the calculator will accept any number of buffer sections. If using more than two, write in the margin.

Survey the slope of each section. If slope is surveyed as zero, record as .01. Refer to table 4 for the surface-condition constant (c).

Section a:	Slope (S)	= _____%	(17)
Ground cover _____	(c)	= _____	(18)
	Distance (L)	= _____	(19)

TABLE 5. — Soil names and hydrologic classifications

Aastad	B	Brickton	C	Dorset	B	Greenwood	A/D
Aasdahl	B	Brill	B	Dovray	C/D	Grimstad	B
Adolph	B/D	Brodale	C	Downs	B	Grogan	B
Adrian	A/D	Brookings	B	Dubuque	B	Growton	B
Afton	C/D	Brophy	A/D	Duelm	A	Grygla	B/D
Ahmeek	C	Brownston	C/D	Duluth	C	Guckeen	C
Alcester	B	Burkhardt	B	Dunbarton	D	Halder	C
Allendale	B	Burnsville	B	Dundas	B/D	Hamar	A/D
Almena	C	Buse	B	Dunnville	B	Hamel	C
Alstad	B	Calamine	C/D	Dusler	C	Hamerly	C
Alvin	B	Calco	C/D	Eckman	B	Hangaard	A/D
Amery	B	Campia	B	Edison	B	Hanska	C
Ames	C/D	Canisteco	C/D	Edwards	B/D	Hantho	B
Ankeny	B	Carlos	A/D	Egeland	B	Harps	B/D
Anoka	B	Caron	A/D	Elderon	B	Harpster	B/D
Antigo	B	Cashel	C	Eleva	B	Hatfield	B/D
Arcola	C	Cathro	A/D	Ely	B	Hattie	C
Aredale	B	Channahon	D	Embden	B	Haug	B/D
Arenzville	B	Chaseburg	B	Emmert	A	Havana	B
Arland	B	Chaska	B/D	Enloe	D	Hayden	B
Arveson	A/D	Chelsea	A	Enstrom	B	Hayfield	B
Arvilla	B	Chetek	B	Erin	B	Hecla	A
Athelwold	B	Chilgren	C	Estelline	B	Hegne	C/D
Atkinson	B	Clarion	B	Estherville	B	Hesch	B
Auburndale	C/D	Clontarf	B	Etter	B	Heyder	B
Augsburg	B/D	Cloquet	B	Everly	B	Hibbing	C
Automba	B	Clyde	B/D	Eyota	A	Hidewood	C
Badger	C/D	Collinwood	C	Fairhaven	B	Hillet	C/D
Barbert	D	Colo	B/D	Fargo	C	Hiwood	A
Barnes	B	Colvin	C/D	Farrar	B	Hixton	B
Baroda	D	Comfrey	B/D	Faxon	B/D	Holdingford	C
Barrington	B	Conic	C	Fayette	B	Houghton	A/D
Barronett	B/D	Copaston	D	Fedji	A	Hubbard	A
Barrows	B/D	Cordova	C/D	Fieldon	B/D	Huntsville	B
Barto	B/D	Cormant	A/D	Finchford	A	Ihlen	B
Baudette	B	Crippin	B	Flak	C	Indus	D
Bearden	C	Crocker	A	Flaming	A	Insula	D
Beauford	D	Crofton	B	Flandreau	B	Isan	A/D
Becker	B	Cromwell	A	Flom	B/D	Isanti	A/D
Bellechester	A	Curran	C	Floyd	B	Jackson	B
Beltrami	B	Cushing	B	Foldahl	B	Joliet	D
Bena	A	Cutfoot	A	Forada	B/D	Joy	B
Benoit	B/D	Cylinder	B	Fordville	B	Judson	B
Beotia	B	Dakota	B	Forman	B	Kamrar	B
Bergland	D	Dalbo	B	Formdale	B	Kanaranzi	B
Bertrand	B	Darfur	B/D	Fossum	A/D	Karlstad	A
Beseman	A/D	Darnen	B	Foxhome	B	Kasota	C
Billet	B	Dassel	B/D	Fram	B	Kasson	C
Biscay	B/D	Dawson	A/D	Freeon	B	Kato	C
Bixby	B	Deerwood	B/D	Freer	C	Kegonsa	B
Blackhoof	C/D	Derinda	C	Frontenac	B	Kennebec	B
Blomford	B/D	Dickey	A	Fulda	C/D	Kenyon	B
Blooming	B	Dickinson	B	Gale	B	Kilkenny	B
Blue Earth	B/D	Dickman	A	Galva	B	Kingsley	B
Bluffton	C/D	Dinsdale	B	Garnes	B	Kingston	
Bold	B	Divide	B	Garwin	C/D	Kittson	C
Boone	A	Dodgeville	B	Glencoe	B/D	Klinger	B
Boots	A/D	Doland	B	Glyndon	B	Kranzburg	B
Borup	B/D	Donaldson	B	Gonvick	B	Kratka	B/D
Braham	B	Donnan	C	Gotham	A	LaPrairie	B
Brainerd	C	Doran	C	Granby	A/D		
Bremer	C	Dorchester	B	Grays	B		

TABLE 5.—Soil names and hydrologic classifications—Continued

Lamont	B	Mosomo	A	Rauville	C/D	Swenoda	B
Lamoure	C	Mt. Carroll	B	Readlyn	B	Syrene	B/D
Langhei	B	Muscatine	B	Redby	B	Talcot	B/D
Langola	B	Muskego	A/D	Renova	B	Tallula	B
Lasa	A	Nebish	B	Renshaw	B	Tama	B
Lawler	B	Nemadji	B	Rib	C	Taopi	C
Lawson	B	Nereson	B	Richwood	B	Tara	B
LeSueur	B	Nessel	B	Rifle	A/D	Tawas	A/D
Lemond	B/D	Newfound	C	Rockton	B	Taylor	C
Lerdal	C	Newglarus	B	Rockwell	B/D	Tell	B
Lester	B	Newry	B	Rockwood	C	Terril	B
Letri	B/D	Newson	A/D	Rolfe	C/D	Tilfer	B/D
Lilah	A	Nicollet	B	Roliss	B/D	Timula	B
Linder	B	Nokasippi	D	Rondeau	A/D	Toddville	B
Lindstrom	B	Nokay	C	Ronneby	C	Toivola	A
Lino	B	Nordness	B	Rosemount	B	Tonka	C/D
Lismore	B	Normania	B	Rosendale	B	Torning	B
Litchfield	A	Northcote	C/D	Roseville	B	Towner	B
Lobo	D	Nowen	B/D	Rosholt	B	Trent	B
Lohnes	A	Noyes	C/D	Rothsay	B	Tripoli	B/D
Lomax	B	Nutley	C	Rushmore	B/D	Trosky	B/D
Loxley	A/D	Nymore	A	Ryan	D	Truman	B
Lupton	A/D	Oak Lake	B	Sac	B	Twig	A/D
Lura	C/D	Ocheyedan	B	Salida	A	Udolpho	B/D
Maddock	A	Ogilvie	B/D	Santiago	B	Ulen	B
Madelia	B/D	Okoboji	B/D	Sargeant	D	Upsala	C
Mahtowa	C/D	Oldham	C/D	Sartell	A	Urness	B/D
Malachy	B	Omega	A	Satore	B	Vallers	C
Marcus	B/D	Onamia	B	Sawmill	B/D	Vasa	B
Markey	A/D	Ontonagon	D	Schapville	C	Ves	B
Marlean	B	Opole	B	Schley	B	Vienna	B
Marna	D	Orion	B	Seaforth	B	Viking	D
Marquette	A	Oronoco	B	Seaton	B	Vlasaty	C
Marshan	B/D	Osakis	B	Seelyeville	A/D	Waccusta	B/D
Marysland	B/D	Oshawa	C/D	Shakopee	C/D	Wadena	B
Mavie	B/D	Ossian	B/D	Shawano	A	Wahpeton	C
Maxcreek	B/D	Ostrander	B	Shible	B	Waldorf	C/D
Maxfield	B/D	Otter	B/D	Shields	C	Warba	B
Mayer	B/D	Otterholt	B	Shocker	C	Warman	B/D
Mazaska	C/D	Paget	C	Shorewood	C	Waskish	A/D
McDonaldsville	C/D	Palms	A/D	Shullsburg	C	Watab	C
McIntosh	B	Palsgrove	B	Sinai	C	Watseka	A
McPaul	B	Parent	B/D	Singsaas	B	Waubay	B
Medary	C	Parnell	C/D	Sioux	A	Waubek	B
Meehan	A/D	Pelan	B	Skyberg	C	Waucoma	B
Menagha	A	Percy	B/D	Sletten	B/D	Waukee	B
Meridian	B	Perella	B/D	Soderville	A	Waukegan	B
Merton	B	Plainfield	A	Sogn	D	Waukon	B
Merwin	A/D	Poinsett	B	Sparta	A	Webster	B/D
Mesaba	C	Pomroy	B	Spencer	C	Whalan	B
Metogga	A/D	Poppleton	A	Spicer	B/D	Wheatville	B
Milaca	C	Port Byron	B	Spillville	B	Whitewood	C/D
Millerville	A/D	Prebish	C/D	Spooner	C/D	Wildwood	C/D
Millington	B	Pringhar	B	Spottswood	B	Wilmington	B
Minneiska	C	Protvin	C	Storden	B	Winger	B/D
Minneopa	B	Quam	B/D	Strandquist	B/D	Wyndmere	B
Minnetonka	D	Quetico	D	Stronghurst	B	Zell	B
Moland	B	Racine	B	Stuntz	C	Zimmerman	A
Moody	B	Radford	B	Suamico	A/D	Zumbro	A
Moose Lake	A/D	Ransom	B	Svea	B	Zwingle	D
Mora	C	Rasset	B	Sverdrup	B		

Note: Two soil groups, such as B/D, indicate the drained/undrained situation.

## Section b:

Slope (S) = \_\_\_\_\_ (20)

Ground cover \_\_\_\_\_ (c) = \_\_\_\_\_ (21)

Distance (L) = \_\_\_\_\_ (22)

Step 8. Enter the number of animals in the lot and the animal type factors from table 6 for chemical oxygen demand (COD) and total phosphorus (P).

Animal Type	Number of		
_____	Animals	=	_____ (23)
	COD Factor	=	_____ (24)
	P Factor	=	_____ (25)
 _____	 Number of	 =	 _____ (26)
	 Animals		
	COD Factor	=	_____ (27)
	P Factor	=	_____ (28)
 _____	 Number of	 =	 _____ (29)
	 Animals		
	COD Factor	=	_____ (30)
	P Factor	=	_____ (31)

\*\* End of data entry \*\*

## Ground-water Pollution Potential

Step 9. Consider the first (upper) buffer section.

(A) Note the soil type as shown on the sketch \_\_\_\_\_.

Determine the hydrologic soil group from table 5, and indicate the soil group and soil factor on the table below.

<u>Hydrologic Soil Group</u>	<u>Soil Factor</u>
A	2
B	1
C	0
D	0

- (B) Note the minimum depth to ground water or bedrock and indicate source of this information (for example: site inspection or SCS - soils - 5 soil interpretation).

Minimum depth \_\_\_\_\_

According to \_\_\_\_\_

Determine the depth factor and indicate on the table below:

<u>Minimum depth</u>	<u>Depth factor</u>
0 - 2 ft	3
2 - 4 ft	2
4 - 6 ft	1
more than 6 ft	0

- (C) Rating value for ground-water pollution:  
Soil factor plus depth factor = \_\_\_\_\_

(32)

**TABLE 6.—Ratio of COD and P produced by various animals to that produced by a 1,000 pound slaughter steer**

<u>Animal type</u>	<u>Design weight<sup>1</sup></u>	<u>COD</u>	<u>P</u>
<i>Pounds</i>			
Slaughter steer .	1,000	1.00	1.00
Young beef . . . .	500	.50	.51
Dairy cow . . . . .	1,400	1.96	.92
Young dairy stock . . . . .	500	.70	.33
Swine . . . . .	200	.17	.27
Feeder pig . . . . .	50	.04	.07
Sheep . . . . .	100	.18	.06
Turkey . . . . .	10	.02	.03
Chicken . . . . .	4	.01	.01
Duck . . . . .	4	.01	.01
Horse . . . . .	1,000	.42	.42

<sup>1</sup>Interpolation of values should be based on the maximum weight animals would be expected to reach.

## Step 10. Results of evaluation:

## Surface water:

Total volume of runoff at the discharge point \_\_\_\_\_ acre-in (33)

COD concentration at the discharge point \_\_\_\_\_ mg/l (34)

Description of discharge point and/or name of  
receiving water if applicable (from Step 1):  
\_\_\_\_\_  
\_\_\_\_\_Animal lot rating for surface-water pollution  
(0 = no hazard, 100 = very severe hazard) \_\_\_\_\_ (35)Ground water: (from line 32) (0 = minor hazard,  
5 = very severe hazard). \_\_\_\_\_ (36)Additional comments:  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_Step 10.9. If the feedlot operation includes separate animal lots  
in immediate proximity to each other that are interdependent  
in use or management, combine ratings for all such animal  
lots and enter the results here.

Total volume of runoff from feedlot \_\_\_\_\_ acre-in

Weighted average COD concentration \_\_\_\_\_ mg/l

Feedlot rating \_\_\_\_\_

Prepared by \_\_\_\_\_ Date \_\_\_\_\_

## Appendix C

### Detailed Instructions for Calculations Using the Hewlett-Packard 97 Calculator

#### Calculating animal lot screening

NOTE -- First follow instructions on back of Screening form.

- A. Turn power switch "on".
- B. Set man-trace-norm switch on "norm" and prgm-run switch on "run".
- C. Insert screening program into calculator. This program is on side 1 of card 1. (Feed printed side up, numbered side leading.)
- D. Press "A". After flickering briefly, display will read "1.00".
- E. Enter information from the screening form. After each complete number entry, press "R/S".
  - CAUTION - Do not depress any key while display is flashing.
  - Note that the spacing of the printout matches the spacing of the screening form.
- F. When information for all animal types has been entered, the display will show "0.00". Press "R/S" to enter the zero from the display, signaling the calculator that there are no additional entries. After the display flickers briefly, the calculator will display and print the surface water pollution hazard screening result.
- G. If an error is made in entering data, or if more than one animal lot is to be screened, it is not necessary to reenter the program card. In either case, simply go back to D above: press "A", etc.
- H. An optional feature allows the user to enter the feedlot area from line 1 of the form (E above) in square feet. If this option is selected, the calculator determines and prints the number of acres. To make this automatic conversion, press "C" (instead of "R/S") after keying in the number of square feet.

#### Calculating animal lot evaluation

- A. Turn power switch "on".
- B. Set man-trace-norm switch on "norm" and prgm-run switch on "run".
- C. Insert program card 2 into calculator (both sides). (Feed printed side up.)
- D. Press "A". After flickering briefly, display will read "2.00".

- E. Enter data from steps 3 - 6 of the evaluation data form. After each complete number entry, press "R/S".
- CAUTION - Do not depress any key while display is flickering.
  - Note that the spacing of the printed tape matches the format of the Animal Lot Evaluation Data Form.
  - WARNING - In Step 6, the calculator enters zeroes automatically where required. It "knows" where because of corresponding zeroes entered in Step 4. Watch the paper tape and do not enter any zeroes from keyboard.
- F. Enter data from Step 7 of the data form.
- If there is no buffer, press "R/S" and proceed to enter data from Step 8, as described in G below.
  - While only two sets of blanks are provided, note that any number of buffer sections may be entered.
  - When information for all buffer sections has been entered, the display will show "0.00". Press "R/S" to enter the zero from the display, signalling the calculator that there are no additional buffer sections.
- G. Enter data from Step 8 of the data form.
- While only three sets of blanks are provided, note that any number of animal types may be entered.
  - When information for all animal types has been entered, the display will show "0.00". Press "R/S" to enter the zero from the display, signalling the calculator that there are no additional animal types.
- H. If an error is made in entering data from the evaluation data form, it is not necessary to reenter card 2. Simply press "A", and proceed with E above after the display reads "2.00".
- I. The calculator will display "3.00" after flickering briefly. Insert program card 3 into calculator (both sides). The display will now read "3.".
- J. Press "R/S". The calculator will continue flickering and will then print the following information for the animal lot:
- total runoff volume (acre-inches)
  - COD concentration at discharge point (parts per million, ppm)
  - animal lot rating
- The calculator will display "4.00" to indicate that card 4 may now be fed into the calculator if design information is desired.
- K. If additional information is desired, insert program card 4 into calculator (both sides). The display will now read "4.".

L. Press "R/S". The calculator will print groups of information on the following factors:

- Runoff volume
- The rating this lot would have if all runoff from Area 2 was diverted
- COD concentrations
- COD loadings
- P concentrations
- P loadings

Details on the format and information are given on the next two pages.

M. To evaluate another animal lot, insert card 2 into calculator and proceed with D above.

N. The following summary of keyboard displays may prove helpful:

- 2.00 -- awaiting entry of first number (rainfall, step 3) from data form
- 3.00 -- awaiting insertion of card 3
- 3. -- card 3 inserted; awaiting the pressing of "R/S"
- 4.00 -- awaiting insertion of card 4
- 4. -- card 4 inserted; awaiting the pressing of "R/S"

O. Two optional features provide user convenience in entering data from Step 4 (E above). If not helpful, these should be disregarded.

- Press "R/S" to enter zero areas from the display; it is not necessary to press "O" when the display shows zero.
- To automatically convert areas from square feet to acres, press "C" (instead of "R/S") after keying in the number of square feet. The calculator will calculate and enter the correct acreage. (Screening does this too.)

#### Additional information available

If desired, additional information about an animal lot may be obtained after the calculator has printed the rating.

The information relates to:

- Runoff volume, acre-inches (A-in);
- The rating this animal lot would have if all Area 2 runoff was diverted from the feedlot watershed area (diverted lot);
- Concentrations of Chemical Oxygen Demand (COD) in parts per million (ppm);
- Loadings of COD in pounds (#);
- Concentrations of Phosphorous (P) in ppm; and
- Loadings of P in #.

The spacing of the accompanying table matches the spacing of the calculator printout. In interpreting the information, the following comments may be helpful.

- Runoff from Areas 1+2+3 is the same as the total runoff volume, output previously by the calculator (line 33 on the data form).
- ppm COD at discharge point is the same as the COD concentration at the discharge point, output previously by the calculator (line 34 on the data form).
- "at feedlot edge" refers to the lower edge of the animal lot.
- "buffer effects" include settling, infiltration, adsorption, interception, and other effects. These depend on the time of contact between runoff water and the ground surface.
- "dilution" refers to the fact that the relatively polluted water from the animal lot, after some cleansing in the buffer, is diluted with runoff from Area 3. Percent reduction due to dilution is positive because dilution reduces concentration of pollutants. Loadings in pounds may be negative because the dilution water contributes additional amounts of pollutants. When calculated pollutant concentrations are less than background levels because the buffer is effective, these percentages are left blank.
- The animal lot rating is based on COD loadings, but the basis for rating is not included in the information listed here. The model estimates the actual COD and P quality of discharge water.

Number printed	Explanation of printout
A -in	Runoff from Area 1
A -in	Runoff from Area 2
A -in	Runoff from Areas 1 + 2
A -in	Runoff from Area 3
A -in	Runoff from Areas 1 + 2 + 3
A -in ppm rating	Runoff from diverted lot COD at discharge point for diverted lot for diverted lot
ppm	COD at feedlot edge
%	reduction from buffer effects
%	reduction due to dilution
ppm	COD at discharge point
#	COD at feedlot edge
%	reduction from buffer effects
%	reduction due to dilution
#	COD at discharge point
ppm	P at feedlot edge
%	reduction from buffer effects
%	reduction due to dilution
ppm	P at discharge point
#	P at feedlot edge
%	reduction from buffer effects
%	reduction due to dilution
#	P at discharge point

## Combined animal lot rating

If a combined rating is required for more than one animal lot on the farm -

FIRST - evaluate each lot separately, using the evaluation program;

THEN - take the outputs (J above) from each lot and use this program to combine them.

- A. Turn power switch "on".
- B. Set man-trace-norm switch on "norm" and prgm-run switch on "run".
- C. Insert program for combining ratings into calculator. This is program 5, on side 2 of card 1. (Feed printed side up, numbered end leading.)
- D. Press "A". After flickering briefly, display will read "5.".
- E. For each animal lot included in the total feedlot operation, enter in order:

- Runoff volume (acre-inches)
- COD concentration at discharge point (ppm)
- Animal lot rating\*

CAUTION - Do not depress any key while display is flashing.

- F. After the information for all animal lots has been entered, the display will show "0.00". Press "R/S" to enter the zero from the display, signalling the calculator that there are no additional entries. After the display flickers briefly, the calculator will combine the information and print:

- total feedlot runoff volume
- average COD concentration at discharge point
- overall feedlot rating

- G. If an error is made in entering data, or if more than one set of animal lot ratings is to be combined, it is not necessary to reenter the program card. In either case, simply go back to D above: press "A", etc.

---

\* If the rating of any animal lot is zero, the calculator will disregard information on that lot. The information may be entered nonetheless so that the calculator tape will show a complete record.

# Detailed Instructions for Calculations Using the Monroe 325 Calculator

## PROGRAM OPERATION SHEET

No. 41

Animal Lot Screening Program

Page 1 of 1

### OPERATING PROCEDURE

#### GENERAL

#### SAMPLE

**FIRST:** Follow instructions on back of Screening form.

Load Cassette ACP WP-4 3/80.

Rewind; latch Ready on tape drive; press 1 on calculator; press Read From Tape on tape drive. Wait until "1.0000" appears in display. Rewind tape by pressing Stop, Rewind, Stop on tape drive.

Program located at: BLOCK 1  
FILE 1

.....  
41 01 01.0  
.....

DEPRESS: Jump/Start-Stop/Start-Stop

-1. 1.00

READ: Program number and location

-2. 1.00

IDENTIFIER:

1. ENTER approximate area of  
animal lot (acres)\*

-3. 1.00  
1.00

2. ENTER approximate distance  
between animal lot and  
discharge point.

.....  
4. 0.

3. ENTER for first animal type:

# of head

.....

COD factor

Continue entering:  
Number of head  
COD factor

.....  
41 01 01.0  
.....

DEPRESS Start-Stop ONCE when all  
information has been  
entered.

-1. 1.00  
-2. 1.00

.....

-3. 5.00

4. READ surface water pollution  
hazard screening result

0.70

.....

2.00  
0.17

Program will return to beginning for  
screening another animal lot.

.....

4. 2.

\* Note--acres = sq. ft. ÷ 43,560.

.....

## PROGRAM OPERATION SHEET

No. 42

Animal Lot Evaluation Program

Page 1

of 6

## OPERATING PROCEDURE

## GENERAL

## SAMPLE

Load Cassette ACP WP-4 3/80.

Rewind; latch Ready on tape drive; press 2 on calculator; press Read From Tape on tape drive. Wait until two appears in display (may show as "2." or "2.00" or "2.0000").

WARNING: Ready key on tape drive must remain latched! This program automatically continues on Blocks 3 & 4.

Program located at: BLOCK 2  
FILE 1

DEPRESS: Jump/Start-Stop/Start-Stop

READ: Program number and location

IDENTIFIER: (Matches step number on  
left side of data form)

3. ENTER Design Rainfall (inches),  
line 1 (line numbers are  
in right margin of data  
form). (To enter a number,  
depress the appropriate  
number keys; then depress  
Start-Stop once.)

.....  
42 01 02.0  
.....  
-3. 4.35

OBSERVE: The spacing of the printed  
tape matches the spacing  
of blanks on the data form.

-4. 0.95  
0.77  
0.00  
0.14  
0.47  
0.00  
0.00  
0.00

4. ENTER size of each area or sub-  
area (acres), lines 2  
through 9. Enter zero for  
lines not used. Note--  
acres= sq. ft.  $\div$  43,560.

-5. 91.00

5. ENTER Soil Cover Complex Number  
(CN) for Area 1 (animal  
lot), line 10.

WARNING: DO NOT press anything while  
display is flashing, now  
or in any subsequent steps!

## PROGRAM OPERATION SHEET

No. 42

Animal Lot Evaluation Program

Page 2

of 6

## OPERATING PROCEDURE

## GENERAL

## SAMPLE

6. ENTER Soil Cover Complex Number (CN) for remaining areas, lines 11 through 16.

WARNING: The calculator enters zeroes automatically where required. It "knows" where because of corresponding zeroes entered in Step 4. Watch the paper tape and do not enter any zeroes from keyboard.

-6. 86.00  
0.00  
79.00  
0.00  
0.00  
0.00

7. If no buffer, DEPRESS Start-Stop ONCE and proceed to Step 8.

-7. 1.00  
0.29  
60.00

If there is any buffer:

-8. 300.00  
1.00  
1.00

ENTER for first buffer section:

Slope (S,%) (line 17)

300.00  
0.50  
0.51

Surface Condition Constant (C) (line 18)

Distance (L, feet) (line 19)

Continue Entering:

Slope (S)

Surface Condition Constant (C)

Distance (L)

SAMPLE  
if there is no buffer:

-6. 74.00  
0.00

DEPRESS Start-Stop ONCE when all buffer sections have been entered.

74.00  
55.00  
100.00  
0.00

8. ENTER for first animal type;

# of head (line 23)

-7.

COD factor (line 24)

-8.

P factor (line 25)

170.00  
0.17  
0.21

Continue entering:

# of head

COD factor

P factor

10.00  
0.50  
0.51

## PROGRAM OPERATION SHEET

No. 42

Animal Lot Evaluation Program

Page 3

of 6

## OPERATING PROCEDURE

## GENERAL

## SAMPLE

NOTE: If any errors were made in entering data, DEPRESS Jump/Start-Stop/Start-Stop and start again by entering Design Rainfall (line 1, Step 3)

After all information has been entered,

9. DEPRESS Start-Stop ONCE for animal lot rating

OBSERVE: Tape drive advancing cassette to Block 3

10. READ:

Total runoff volume  
(acre-inches) (line 33)

.....

10.

7.

4516.

COD concentration at  
discharge point (parts per  
million, ppm) (line 34)

41.

Animal lot rating (line 35)

.....

AT THIS POINT YOU HAVE TWO OPTIONS.

OPTION 1 - To evaluate another  
animal lot,

RETURN to the top of Page 1 and read Block 2 from the tape. However, as "2" already appears in the display, it is not necessary to press "2" on the calculator.

OPTION 2 - To obtain additional information, if requested by the technician,

## PROGRAM OPERATION SHEET

 No. 42  
 Page 4 of 6

Animal Lot Evaluation Program

## OPERATING PROCEDURE

## GENERAL

## SAMPLE

DEPRESS Start-Stop ONCE

READ:

.....

11.

3.19

2.82

6.00

11. \*Information on runoff volume

1.06

7.06

OBSERVE: Tape drive advancing  
cassette to Block 4

.....

12.

4.

4.45

32.

12. \*Information on the rating this  
lot would have if all runoff  
from Area 2 were diverted.

.....

13.1

4.500.

13.1 \*Information on COD concentra-  
tions, ppm

61.

14.

13.2 \*Information on COD loadings,  
pounds

4.516.

13.2

6.130.

14.1 \*Information on P  
concentrations, ppm

61.

-1.

14.2 \*Information on P  
loadings, pounds

2.429.

.....

14.1

85.

To evaluate another animal lot,

55.

14.

RETURN to the top of Page 1 and  
read Block 2 from the tape.  
However, as "2" already  
appears in the display, it is  
not necessary to press "2"  
on the calculator.

23.

14.2

110.

\*Details of the format and informa-  
tion are given on the next two  
pages.

55.

-1.

52.

.....

## Additional information available

If desired, additional information about an animal lot may be obtained after the calculator has printed the rating.

The information relates to:

- Runoff volume, acre-inches ( A-in);
- The rating this animal lot would have if all Area 2 runoff were diverted from the feedlot watershed area (diverted lot);
- Concentrations of Chemical Oxygen Demand (COD) in parts per million (ppm);
- Loadings of COD in pounds (#);
- Concentrations of Phosphorous (P) in ppm; and
- Loadings of P in #.

The spacing of the accompanying table matches the spacing of the calculator printout. In interpreting the information, the following comments (keyed to the identifiers and line reference letters) may be helpful.

- Line 11(e) is the same as the total runoff volume, output previously by the calculator (line 33 on the data form).
- Line 13.1(d) is the same as the COD concentration at the discharge point, output previously by the calculator (line 34 on the data form).
- "at feedlot edge" refers to the lower edge of the animal lot.
- "buffer effects" include settling, infiltration, absorption, interception, and other effects. These depend on the time of contact between runoff water and the ground surface.
- "dilution" refers to the fact that the relatively polluted water from the animal lot, after some cleansing in the buffer, is diluted with runoff from Area 3. Lines 13.1(c) and 14.1(c) are positive because dilution reduces concentration of pollutants. Lines 13.2(c) and 14.2(c) are negative because the dilution water contributes additional amounts of pollutants. When calculated pollutant concentrations are less than background levels because the buffer is effective, these percentages are left blank.
- The animal lot rating is based on COD loadings, but the basis for rating is not included in the information listed here. The model estimates the actual COD and P quality of discharge water.

## PROGRAM OPERATION SHEET

No. 42

Animal Lot Evaluation Program

Page 6

of 6

Identifier (Monroe & Compucorp only)	Number Printed	Line Refer- ence	Explanation
.... 11	A -in A -in A -in  A -in A -in	    (e)	Runoff from Area 1 Runoff from Area 2 Runoff from Areas 1 + 2  Runoff from Area 3 Runoff from Areas 1 + 2 + 3
.... 12	A -in ppm rating		Runoff from diverted lot COD at disch pt. for diverted lot for diverted lot
.... 13.1	ppm  % %  ppm	(a) (b) (c) (d)	COD at feedlot edge reduction from buffer effects reduction due to dilution COD at discharge point
13.2	#  % %  #	(a) (b) (c) (d)	COD at feedlot edge reduction from buffer effects reduction due to dilution COD at discharge point
.... 14.1	ppm  % %  ppm	(a) (b) (c) (d)	P at feedlot edge reduction from buffer effects reduction due to dilution P at discharge point
14.2	#  % %  #	(a) (b) (c) (d)	P at feedlot edge reduction from buffer effects reduction due to dilution P at discharge point
....			

# PROGRAM OPERATION SHEET

No. 43

Combining Animal Lot Ratings

Page 1 of 2

## OPERATING PROCEDURE

### GENERAL

### SAMPLE

If technician requests combined rating for more than one animal lot on the farm-

FIRST evaluate each lot separately, using Program 42 (the evaluation program);

THEN take the outputs (Identifier 10) from each lot and use this program to combine them.

Load Cassette ACP WP-4 3/80

Latch Ready on tape drive; press 5 on calculator; press Read From Tape on tape drive. Wait until five appears in display (may show as "5." or "5.0000"). Rewind tape by pressing Stop, Rewind, Stop on tape drive.

Program located at: BLOCK 5  
FILE 1

DEPRESS: Jump/Start-Stop/Start-Stop

READ: Program number and location

ENTER for first animal lot:

Runoff Volume (acre-inches)  
(line 33)

.....  
43 01 05.0  
.....

COD concentration at discharge  
point (ppm) (line 34)

7.  
4515.

Animal lot rating (line 35)\*

41.

Continue entering:

Runoff volume

28.  
805.

COD concentration at discharge point

0.

Animal lot rating\*

CONTINUED ON NEXT PAGE

\*If the rating of any animal lot is zero, the calculator will disregard information on that lot. The information may be entered nonetheless so that the calculator tape will show a complete record.

# PROGRAM OPERATION SHEET

No. 43

Page 2

of 2

Combining Animal Lot Ratings

## OPERATING PROCEDURE

### GENERAL

### SAMPLE

DEPRESS: Start-Stop ONCE when all  
animal lots have been  
entered.

.....

.....

10.9

READ:

7.

10.9 Total feedlot runoff volume

4515.

Average COD conc. at  
discharge point

41.

.....

Overall feedlot rating

.....

**Appendix D**  
**Calculator Programs**  
**Program for**  
**Hewlett-Packard 67/97/41C Calculator**

**Screening program**  
**CARD 1**

			046	RCLD	36 14	013	2	32	059	ST+2	35-55 02	
001	*LBLA	21 11	047	÷	-24	014	SPC	16-11	060	RCL5	36 05	
002	CLRG	16-53	048	EEX	-23	015	R/S	51	061	ST+2	35-55 02	
003	3	03	049	2	02	016	ST09	35 05	062	RCL8	36 08	
004	.	-62	050	X>Y?	16-34	017	SPC	16-11	063	ST01	35 01	
005	2	02	051	X≠Y	-41	018	SPC	16-11	064	RCL2	36 02	
006	8	08	052	RCLB	36 12	019	*LBL1	21 01	065	+	-55	
007	9	09	053	X≠Y	-41	020	R/S	51	066	RCL3	36 03	
008	5	05	054	÷	-24	021	*LBL4	21 16 11	067	+	-55	
009	ST0A	35 11	055	CHS	-22	022	ST01	35 45	068	ST0A	35 11	
010	5	05	056	RCLA	36 11	023	0	00	069	3	03	
011	.	-62	057	+	-55	024	DSZI	16 25 46	070	0	00	
012	8	08	058	10*	16 33	025	GT01	22 01	071	ST0B	35 12	
013	4	04	059	RCLC	36 15	026	SPC	16-11	072	RCL2	36 02	
014	1	01	060	X≠Y?	16-35	027	SPC	16-11	073	X≠Y	-41	
015	1	01	061	GT02	22 02	028	8	. 08	074	-	-45	
016	ST0B	35 12	062	0	00	029	ST01	35 46	075	X<0?	16-45	
017	4	04	063	GT03	22 03	030	RCL1	36 45	076	GT03	22 03	
018	3	03	064	*LBL2	21 02	031	P/S	16-51	077	ST0C	35 13	
019	5	05	065	2	02	032	ST05	35 05	078	GT04	22 04	
020	6	06	066	*LBL3	21 03	033	P/S	16-51	079	*LBLC	21 13	
021	0	00	067	SPC	16-11	034	GSB6	23 16 13	080	RCLB	36 12	
022	ST0C	35 13	068	SPC	16-11	035	SPC	16-11	081	÷	-24	
023	1	01	069	PRTX	-14	036	SPC	16-11	082	PRTX	-14	
024	SPC	16-11	070	SPC	16-11	037	DSZI	16 25 46	083	GT04	22 16 11	
025	R/S	51	071	RTN	24	038	GSB6	23 16 12	084	*LBL6	21 16 12	
026	*LBL4	21 16 11	072	*LBLC	21 13	039	DSZI	16 25 46	085	RCL1	36 45	
027	SPC	16-11	073	RCLC	36 13	040	GSB6	23 16 12	086	X#0?	16-42	
028	SPC	16-11	074	÷	-24	041	DSZI	16 25 46	087	GT06	22 16 13	
029	ST0D	35 14	075	PRTX	-14	042	RCL9	36 09	088	PRTX	-14	
030	R/S	51	076	GT06	22 16 11	043	ST×1	35-35 45	089	RTN	24	
031	SPC	16-11	077	R/S	51	044	DSZI	16 25 46	090	*LBL6	21 16 12	
032	SPC	16-11	Evaluation program				045	SPC	16-11	091	R/S	51
033	ST0E	35 15	CARD 2				046	*LBL2	21 02	092	EEX	-23
034	*LBL6	21 00	001	*LBLA	21 11	047	GSB6	23 16 12	093	3	05	
035	R/S	51	002	CLRG	16-53	048	DSZI	16 25 46	094	X≠Y	-41	
036	X#0?	16-43	003	P/S	16-51	049	GT02	22 02	095	÷	-24	
037	GT01	22 01	004	CLRG	16-53	050	RCL4	36 04	096	1	01	
038	R/S	51	005	4	04	051	RCL2	36 02	097	0	00	
039	x	-35	006	3	03	052	+	-55	098	-	-45	
040	ST+1	35-55 31	007	5	05	053	RCL1	36 01	099	ENT↑	-21	
041	SPC	16-11	008	6	06	054	+	-55	100	ENT↑	-21	
042	0	00	009	0	00	055	ST+3	35-55 03	101	.	-62	
043	GT03	22 03	010	ST0B	35 12	056	RCL7	36 07	102	2	02	
044	*LBL1	21 01	011	6	06	057	ST02	35 02	103	x	-35	
045	RCL1	36 01	012	ST01	35 46	058	RCL6	36 06	104	CHS	-22	

CARD 2—Cont.			158	*LBL6	21 06	212	2	02	039	0	00
105	RCL9	36 09	159	PzS	16-51	213	÷	-24	040	ST06	35 06
106	+	-55	160	CLX	-51	214	+	-55	041	ST08	35 08
107	X²	53	161	.	-62	215	10*	16 33	042	*LBL2	21 02
108	XZY	-41	162	1	01	216	RTN	24	043	PzS	16-51
109	.	-62	163	8	06	217	*LBLc	21 16 15	044	RCL0	36 00
110	8	08	164	GSBd	23 16 14	218	RCL5	36 05	045	X=0?	16-43
111	x	-35	165	R/S	51	219	÷	-24	046	GT03	22 03
112	RCL9	36 09	166	XZY	-41	220	EEX	-23	047	2	02
113	+	-55	167	÷	-24	221	2	02	048	7	07
114	÷	-24	168	ST+0	35-55 00	222	X>Y?	16-34	049	.	-62
115	STX1	35-35 45	169	PzS	16-51	223	XZY	-41	050	9	09
116	RTN	24	170	*LBL7	21 07	224	RTN	24	051	CHS	-22
117	*LBL3	21 03	171	0	00	Evaluation program CARD 3					
118	RCL2	36 02	172	SPC	16-11						
119	ST08	35 12	173	R/S	51	001	DSP0	-63 00	052	ST06	35 06
120	*LBL4	21 04	174	X=0?	16-42	002	.	-62	053	4	04
121	RCLB	36 12	175	GT05	22 05	003	2	02	054	2	02
122	RCL1	36 01	176	*LBL8	21 08	004	2	02	055	.	-62
123	+	-55	177	SPC	16-11	005	7	07	056	8	08
124	ST08	35 12	178	R/S	51	006	ST0E	35 15	057	ST07	35 07
125	SPC	16-11	179	X=0?	16-43	007	RCL5	36 05	058	4	04
126	SPC	16-11	180	GT09	22 09	008	X=0?	16-43	059	9	09
127	PzS	16-51	181	ENT†	-21	009	GT04	22 04	060	.	-62
128	0	00	182	ENT†	-21	010	RCL0	36 00	061	3	03
129	R/S	51	183	R/S	51	011	X=0?	16-43	062	CHS	-22
130	X=0?	16-42	184	x	-35	012	GT01	22 01	063	ST08	35 08
131	GT05	22 05	185	ST+3	35-55 03	013	1	01	064	5	05
132	1	01	186	R4	-31	014	5	05	065	0	00
133	ST00	35 00	187	R/S	51	015	.	-62	066	.	-62
134	PzS	16-51	188	x	-35	016	9	09	067	5	05
135	ST00	35 00	189	ST+4	35-55 04	017	5	05	068	ST09	35 09
136	0	00	190	0	00	018	ST06	35 06	069	RCL0	36 00
137	ST09	35 09	191	GT08	22 08	019	.	-62	070	LOG	16 32
138	PzS	16-51	192	*LBL9	21 09	020	0	00	071	GSBb	23 16 12
139	GT08	22 08	193	RCL3	36 03	021	3	03	072	*LBL3	21 03
140	*LBL5	21 05	194	GSBe	23 16 15	022	3	03	073	6	06
141	R/S	51	195	4	04	023	ST07	35 07	074	ST01	35 46
142	CHS	-22	196	5	05	024	2	02	075	GSBd	23 16 14
143	1	01	197	x	-35	025	1	01	076	PzS	16-51
144	+	-55	198	ST03	35 03	026	.	-62	077	ST00	35 00
145	X=0?	16-43	199	RCL4	36 04	027	2	02	078	PzS	16-51
146	GT06	22 06	200	GSBe	23 16 15	028	CHS	-22	079	8	08
147	1	01	201	.	-62	029	ST08	35 08	080	ST01	35 46
148	-	-45	202	8	08	030	.	-62	081	GSBd	23 16 14
149	GSBd	23 16 14	203	5	05	031	0	00	082	ST00	35 00
150	2	02	204	x	-35	032	3	03	083	PzS	16-51
151	X>Y?	16-34	205	ST04	35 04	033	6	06	084	GT04	22 04
152	XZY	-41	206	PzS	16-51	034	ST09	35 09	085	*LBLb	21 16 12
153	R/S	51	207	3	03	035	RCL0	36 00	086	ENT†	-21
154	XZY	-41	208	RTN	24	036	GSBb	23 16 12	087	ENT†	-21
155	÷	-24	209	*LBLd	21 16 14	037	GT02	22 02	088	RCL9	36 09
156	ST+0	35-55 00	210	XZY	-41	038	*LBL1	21 01	089	x	-35
157	GT07	22 07	211	LOG	16 32				090	ST+8	35-55 08
									091	R4	-31
									092	RCL7	36 07

**CARD 3 — Cont.**

093	x	-35	146	RCL0	36 00	200	RCLD	36 14	043	x	-35
094	RCL6	36 06	147	x	-35	201	PRTX	-14	044	P#S	16-51
095	+	-55	148	RCL3	36 03	202	DSP2	-63 02	045	RCL3	36 03
096	GSBe	23 16 13	149	RCL9	36 09	203	4	04	046	P#S	16-51
097	ST06	35 06	150	x	-35	204	SPC	16-11	047	RCL9	36 09
098	RCL8	36 08	151	+	-55	205	SPC	16-11	048	x	-35
099	GSBe	23 16 13	152	RCLA	36 11	206	R/S	51	049	+	-55
100	ST08	35 08	153	=	-24				050	RCLA	36 11
101	RTN	24	154	ST07	35 07				051	=	-24
102	*LBL6	21 16 13	155	1	01				052	ST07	35 07
103	X<0?	16-45	156	1	01				053	P#S	16-51
104	GT09	22 05	157	2	02				054	RCL1	36 01
105	EEX	-23	158	.	-62	001	SPC	16-11	055	RCL8	36 08
106	2	02	159	5	05	002	DSP2	-63 02	056	x	-35
107	X>Y?	16-34	160	X>Y?	16-34	003	RCL1	36 01	057	RCL0	36 00
108	XZY	-41	161	GT05	22 05	004	RND	16 24	058	x	-35
109	RTN	24	162	RCLB	36 12	005	PRTX	-14	059	P#S	16-51
110	*LBL9	21 09	163	RCL8	36 08	006	RCL2	36 02	060	ST04	35 04
111	0	00	164	x	-35	007	RND	16 24	061	P#S	16-51
112	RTN	24	165	RCL0	36 00	008	PRTX	-14	062	RCL3	36 03
113	*LBLd	21 16 14	166	x	-35	009	RCL1	36 01	063	RCL9	36 09
114	RCLi	36 45	167	RCLi	36 15	010	RCL2	36 02	064	x	-35
115	GSBe	23 16 15	168	x	-35	011	+	-55	065	P#S	16-51
116	ST0i	35 45	169	LOG	16 32	012	RND	16 24	066	+	-55
117	P#S	16-51	170	2	02	013	PRTX	-14	067	RCL1	36 01
118	RCLi	36 45	171	-	-45	014	SPC	16-11	068	=	-24
119	P#S	16-51	172	X<0?	16-45	015	RCL3	36 03	069	ST02	35 02
120	GSBe	23 16 15	173	GT05	22 05	016	RND	16 24	070	1	01
121	RCLi	36 45	174	3	03	017	PRTX	-14	071	1	01
122	x	-35	175	=	-24	018	RCLA	36 11	072	2	02
123	RTN	24	176	RCLA	36 11	019	RND	16 24	073	.	-62
124	*LBL4	21 16 15	177	LOG	16 32	020	PRTX	-14	074	5	05
125	EEX	-23	178	.	-62	021	SPC	16-11	075	X>Y?	16-34
126	2	02	179	1	01	022	SPC	16-11	076	GT01	22 01
127	=	-24	180	x	-35	023	DSP0	63 00	077	RCL4	36 04
128	1	01	181	.	-62	024	RCL1	36 01	078	RCLi	36 15
129	-	-45	182	8	08	025	RCL3	36 03	079	x	-35
130	RTN	24	183	+	-55	026	+	-55	080	LOG	16 32
131	*LBL4	21 04	184	x	-35	027	P#S	16-51	081	2	02
132	P#S	16-51	185	EEX	-23	028	ST01	35 01	082	-	-45
133	RCL3	36 03	186	2	02	029	0	00	083	X<0?	16-45
134	P#S	16-51	187	x	-35	030	ST03	35 03	084	GT01	22 01
135	ST08	35 08	188	RND	16 24	031	RCL4	36 04	085	3	03
136	6	06	189	ST0D	35 14	032	ST08	35 08	086	=	-24
137	0	00	190	*LBL5	21 05	033	2	02	087	RCL1	36 01
138	ST09	35 09	191	SPC	16-11	034	ST09	35 09	088	LOG	16 32
139	RCLC	36 13	192	RCLA	36 11	035	RCLC	36 13	089	.	-62
140	x	-35	193	RND	16 24	036	x	-35	090	1	01
141	RCL8	36 08	194	PRTX	-14	037	RCL8	36 08	091	x	-35
142	RCLB	36 12	195	SPC	16-11	038	RCLB	36 12	092	.	-62
143	x	-35	196	RCL7	36 07	039	x	-35	093	6	06
144	+	-55	197	PRTX	-14	040	+	-55	094	+	-55
145	ST06	35 06	198	SPC	16-11	041	ST06	35 06	095	x	-35
			199	SPC	16-11	042	RCL0	36 00	096	EEX	-23

**Additional information**
**CARD 4**

001	SPC	16-11	051	ST07	35 07
002	DSP2	-63 02	052	P#S	16-51
003	RCL1	36 01	053	RCL1	36 01
004	RND	16 24	054	RCL8	36 08
005	PRTX	-14	055	x	-35
006	RCL2	36 02	056	RCL0	36 00
007	RND	16 24	057	x	-35
008	PRTX	-14	058	P#S	16-51
009	RCL1	36 01	059	ST04	35 04
010	RCL2	36 02	060	P#S	16-51
011	+	-55	061	RCL3	36 03
012	RND	16 24	062	RCL9	36 09
013	PRTX	-14	063	x	-35
014	SPC	16-11	064	P#S	16-51
015	RCL3	36 03	065	+	-55
016	RND	16 24	066	RCL1	36 01
017	PRTX	-14	067	=	-24
018	RCLA	36 11	068	ST02	35 02
019	RND	16 24	069	1	01
020	PRTX	-14	070	1	01
021	SPC	16-11	071	2	02
022	SPC	16-11	072	.	-62
023	DSP0	63 00	073	5	05
024	RCL1	36 01	074	X>Y?	16-34
025	RCL3	36 03	075	GT01	22 01
026	+	-55	076	RCL4	36 04
027	P#S	16-51	077	RCLi	36 15
028	ST01	35 01	078	x	-35
029	0	00	079	LOG	16 32
030	ST03	35 03	080	2	02
031	RCL4	36 04	081	-	-45
032	ST08	35 08	082	X<0?	16-45
033	2	02	083	GT01	22 01
034	ST09	35 09	084	3	03
035	RCLC	36 13	085	=	-24
036	x	-35	086	RCL1	36 01
037	RCL8	36 08	087	LOG	16 32
038	RCLB	36 12	088	.	-62
039	x	-35	089	1	01
040	+	-55	090	x	-35
041	ST06	35 06	091	.	-62
042	RCL0	36 00	092	6	06
			093	+	-55
			094	x	-35
			095	EEX	-23
			096		

# **CARD 4—Cont.**

097	2	02	150	RCL7	36 07	003	CLRG	16-53	057	RCL4	36 04
098	x	-35	151	RND	16 24	004	.	-62	058	LOG	16 32
099	RND	16 24	152	PRTX	-14	005	0	00	059	RCL2	36 02
100	ST03	35 03	153	SPC	16-11	006	3	03	060	x	-35
101	*LBL1	21 01	154	SPC	16-11	007	ST01	35 01	061	RCL3	36 03
102	SPC	16-11	155	RCL6	36 06	008	.	-62	062	+	-55
103	RCL1	36 01	156	RCL6	36 15	009	1	01	063	RCL6	36 06
104	RND	16 24	157	x	-35	010	ST02	35 02	064	LOG	16 32
105	PRTX	-14	158	RND	16 24	011	.	-62	065	RCL1	36 01
106	RCL2	36 02	159	PRTX	-14	012	8	08	066	÷	-24
107	RND	16 24	160	SPC	16-11	013	ST03	35 03	067	x	-35
108	PRTX	-14	161	RCL0	36 00	014	5	05	068	X<0?	16-45
109	RCL3	36 03	162	GSBe	23 16 15	015	SPC	16-11	069	0	02
110	PRTX	-14	163	RCL9	36 09	016	R/S	51	070	ST09	35 09
111	SPC	16-11	164	RCL7	36 07	017	*LBL1	21 01	071	*LBL4	21 04
112	SPC	16-11	165	X>Y?	16-34	018	X=0?	16-43	072	RCL8	36 08
113	PzS	16-51	166	GT06	22 06	019	GT03	22 03	073	SPC	16-11
114	GSBE	23 15	167	SPC	16-11	020	ST0A	35 11	074	PRTX	-14
115	PzS	16-51	168	GT07	22 07	021	R/S	51	075	SPC	16-11
116	*LBL6	21 15	169	*LBL6	21 06	022	ST0B	35 12	076	SPC	16-11
117	RCL7	36 07	170	RCL4	36 11	023	R/S	51	077	RCL9	36 09
118	RCL6	36 06	171	RCL5	36 05	024	X=0?	16-43	078	RND	16 24
119	RCL0	36 00	172	x	-35	025	GT02	22 02	079	PRTX	-14
120	x	-35	173	GSBe	23 16 15	026	RCL1	36 01	080	SPC	16-11
121	X<0?	16-42	174	*LBL7	21 07	027	x	-35	081	SPC	16-11
122	÷	-24	175	SPC	16-11	028	RCL4	36 11	082	RTN	24
123	ST05	35 05	176	RCL7	36 07	029	LOG	16 32	083	R/S	51
124	SPC	16-11	177	RCL4	36 11	030	RCL2	36 02			
125	RCL6	36 06	178	x	-35	031	x	-35			
126	RCLB	36 12	179	RCL6	36 15	032	RCL3	36 03			
127	RCLC	36 13	180	x	-35	033	+	-55			
128	+	-55	181	RND	16 24	034	÷	-24			
129	÷	-24	182	PRTX	-14	035	10x	16 33			
130	RND	16 24	183	0	00	036	ST+6	35-55 06			
131	PRTX	-14	184	SPC	16-11	037	RCL4	36 11			
132	SPC	16-11	185	SPC	16-11	038	ST+4	35-55 04			
133	RCL0	36 00	186	RTN	24	039	RCLB	36 12			
134	GSBe	23 16 15	187	*LBL6	21 16 15	040	x	-35			
135	RCL5	36 05	188	CHS	-22	041	ST+5	35-55 05			
136	RCL7	36 07	189	1	01	042	*LBL2	21 02			
137	X>Y?	16-34	190	+	-55	043	SPC	16-11			
138	GT04	22 04	191	EEX	-23	044	0	00			
139	SPC	16-11	192	2	02	045	R/S	51			
140	GT05	22 05	193	x	-35	046	GT01	22 01			
141	*LBL4	21 04	194	RND	16 24	047	*LBL3	21 03			
142	RCLB	36 12	195	PRTX	-14	048	SPC	16-11			
143	RCLC	36 13	196	RTN	24	049	RCL4	36 04			
144	+	-55	197	R/S	51	050	PRTX	-14			
145	RCL5	36 05				051	X=0?	16-43			
146	x	-35				052	GT04	22 04			
147	GSBe	23 16 15				053	RCL5	36 05			
148	*LBL5	21 05				054	RCL4	36 04			
149	SPC	16-11				055	÷	-24			
						056	ST08	35 08			

## **Combining ratings CARD 5**

## **Preliminary evaluation CARD 6**

001	*LBLA	21 11
002	CLRG	16-53
003	6	06
004	SPC	16-11
005	R/S	51
006	*LBL1	21 01
007	R/S	51
008	1	01
009	X>Y?	16-32
010	GT02	22 02
011	R/S	51
012	GT03	22 03
013	*LBL2	21 02
014	R4	-31
015	CHS	-22
016	XzY	-41
017	LOG	16 32
018	2	02
019	÷	-24
020	+	-55
021	10x	16 33
022	2	02

<b>CARD 6—Cont.</b>			042	G8B4	23	16	11	062	5	05	082	*LBL0	21	00	
023	X>Y?	16-34	043	SPC		16-11		063	.	-62	083	0		00	
024	X#Y	-41	044	R/S		51		064	8	08	084	GT05	22	05	
025	R/S	51	045	*LBL0	21	16	13	065	4	04	085	*LBL0	21	16	
026	X#Y	-41	046	ST02		35	02	066	1	01	086	2		02	
027	÷	-24	047	SPC		16-11		067	1	01	087	*LBL5	21	05	
028	ST+1	35-55	048	SPC		16-11		068	RCL3	36	03	088	PRTX	-14	
029	*LBL3	21	049	R/S		51		069	÷	-24	089	SPC	16-11		
030	0	00	050	*LBL4	21	04		070	CHS	-22	090	SPC	16-11		
031	SPC	16-11	051	R/S		51		071	2	02	091	RTN	24		
032	R/S	51	052	X		-35		072	.	-62	092	*LBL0	21	13	
033	X#0?	16-42	053	ST+3	35-55	03		073	9	05	093	4		04	
034	GT01	22	054	0		00		074	8	08	094	3		03	
035	SPC	16-11	055	SPC		16-11		075	8	08	095	5		05	
036	RCL1	36	056	R/S		51		076	3	03	096	6		06	
037	8	08	057	X#0?		16-42		077	+	-55	097	0		00	
038	5	05	058	GT04		22	04	078	10*	16	33	098	÷	-24	
039	1	01	059	SPC		16-11		079	RCL1	36	01	099	PRTX	-14	
040	X#Y?	16-35	060	RCL2		36	02	080	X#Y?	16-35		100	GT00	22	
041	GT00	22	061	ST÷3	35-24	03		081	GT00	22	16	11	101	R/S	51

**Program for  
Monroe 325/Compucorp 327 Calculator**

<b>Screening program BLOCK 1</b>			•027	035	P A	•055	000	0
•001	001	1	•028	002	2	•056	201	L 1
•002	032	I D	•029	013	S	•057	112	D T
•003	035	P A	•030	032	I D	•058	035	P A
•004	035	P A	•031	034	PT	•059	004	4
•005	112	D T	•032	033	S S	•060	032	I D
•006	004	4	•033	034	PT	•061	034	PT
•007	001	1	•034	300	ST	•062	310	RC
•008	015	/	•035	001	1	•063	002	2
•009	001	1	•036	035	P A	•064	024	+
•010	015	/	•037	003	3	•065	310	RC
•011	001	1	•038	013	S	•066	000	0
•012	012	d	•039	032	I D	•067	020	=
•013	000	0	•040	034	PT	•068	300	ST
•014	015	/	•041	200	L 0	•069	002	2
•015	034	PT	•042	000	0	•070	022	-
•016	112	D T	•043	033	S S	•071	001	1
•017	137	CA	•044	354	JC	•072	000	0
•018	222	DP	•045	001	1	•073	000	0
•019	001	1	•046	034	PT	•074	300	ST
•020	013	S	•047	023	x	•075	003	3
•021	032	I D	•048	033	S S	•076	020	=
•022	034	PT	•049	034	PT	•077	355	JC
•023	033	S S	•050	020	=	•078	002	2
•024	034	PT	•051	301	ST+	•079	310	RC
•025	300	ST	•052	002	2	•080	002	2
•026	000	0	•053	035	P A	•081	350	J
			•054	350	J	•082	003	3

# BLOCK 1—Cont.

•083	202	L	2
•084	310	RC	
•085	003		3
•086	203	L	3
•087	063	½	
•088	023	x	
•089	005		5
•090	012	d	
•091	010		8
•092	004		4
•093	001		1
•094	001		1
•095	020	=	
•096	013	S	
•097	021	+	
•098	003		3
•099	012	d	
•100	002		2
•101	010		8
•102	011		9
•103	003		3
•104	020	=	
•105	161	L-1	
•106	022	-	
•107	310	RC	
•108	001		1
•109	020	=	
•110	220	DP	0
•111	355	JC	
•112	004		4
•113	000		0
•114	350	J	
•115	005		5
•116	204	L	4
•117	002		2
•118	205	L	5
•119	034	PT	
•120	035	P A	
•121	112	D T	
•122	035	P A	
•123	222	DP	2
•124	350	J	
•125	033	S S	

## Evaluation program BLOCK 2

•001	002		2
•002	032	I D	
•003	035	P A	
•004	035	P A	

•005	112	D T	
•006	004		4
•007	002		2
•008	015	/	
•009	001		1
•010	015	/	
•011	002		2
•012	012	d	
•013	000		0
•014	015	/	
•015	034	PT	
•016	112	D T	
•017	137	CA	
•018	222	DP	2
•019	003		3
•020	013	S	
•021	032	I D	
•022	034	PT	
•023	000		0
•024	033	S S	
•025	034	PT	
•026	300	ST	
•027	000		0
•028	035	F A	
•029	004		4
•030	013	S	
•031	032	I D	
•032	034	PT	
•033	000		0
•034	033	S S	
•035	034	PT	
•036	300	ST	
•037	001		1
•038	300	ST	
•039	012	d	
•040	000		0
•041	033	S S	
•042	034	PT	
•043	300	ST	
•044	002		2
•045	000		0
•046	033	S S	
•047	034	PT	
•048	300	ST	
•049	003		3
•050	000		0
•051	033	S S	
•052	034	PT	
•053	300	ST	
•054	004		4
•055	000		0
•056	033	S S	

•057	034	PT	
•058	300	ST	
•059	005		5
•060	000		0
•061	033	S S	
•062	034	PT	
•063	300	ST	
•064	006		6
•065	000		0
•066	033	S S	
•067	034	PT	
•068	300	ST	
•069	007		7
•070	000		0
•071	033	S S	
•072	034	PT	
•073	300	ST	
•074	010		8
•075	035	P A	
•076	005		5
•077	013		S
•078	032	I D	
•079	034	PT	
•080	310	RC	
•081	001		1
•082	360	B	
•083	013		S
•084	303	STx	
•085	001		1
•086	035	P A	
•087	006		6
•088	013		S
•089	032	I D	
•090	034	PT	
•091	310	RC	
•092	002		2
•093	360	B	
•094	013		S
•095	303	STx	
•096	002		2
•097	310	RC	
•098	003		3
•099	360	B	
•100	013		S
•101	303	STx	
•102	003		3
•103	310	RC	
•104	000		0
•105	303	STx	
•106	004		4
•107	035	P A	
•108	310	RC	

BLOCK 2—Cont.

•109	005	5		•160	005	5	•212	021	+
•110	360	B		•161	000	0	•213	310	RC
•111	013	S		•162	300	ST	•214	000	0
•112	303	STx		•163	006	6	•215	020	=
•113	005	5		•164	300	ST	•216	162	SQ
•114	310	RC		•165	007	7	•217	320	XC
•115	006	6		•166	300	ST	•218	013	S
•116	360	B		•167	010	8	•219	023	x
•117	013	S		•168	035	P A	•220	012	d
•118	303	STx		•169	007	7	•221	010	8
•119	006	6		•170	013	S	•222	021	+
•120	310	RC		•171	032	I D	•223	310	RC
•121	007	7		•172	034	PT	•224	000	0
•122	360	B		•173	000	0	•225	020	=
•123	013	S		•174	033	S S	•226	063	½
•124	303	STx		•175	300	ST	•227	023	x
•125	007	7		•176	013	S	•228	310	RC
•126	310	RC		•177	300	ST	•229	013	S
•127	010	8		•178	000	0	•230	020	=
•128	360	B		•179	351	JC	•231	030	RT
•129	013	S		•180	001	1	•232	201	L 1
•130	303	STx		•181	001	1	•233	354	JC
•131	010	8		•182	300	ST	•234	005	5
•132	310	RC		•183	012	d	•235	034	PT
•133	002	2		•184	300	ST	•236	033	S S
•134	021	+		•185	013	S	•237	034	PT
•135	310	RC		•186	035	P A	•238	013	S
•136	003	3		•187	350	J	•239	300	ST
•137	021	+		•188	005	5	•240	004	4
•138	310	RC		•189	213	L S	•241	021	+
•139	004	4		•190	351	JC	•242	001	1
•140	020	=		•191	000	0	•243	020	=
•141	300	ST		•192	034	PT	•244	354	JC
•142	002	2		•193	030	RT	•245	003	3
•143	310	RC		•194	200	L 0	•246	360	B
•144	005	5		•195	033	S S	•247	012	d
•145	021	+		•196	034	PT	•248	022	-
•146	310	RC		•197	063	½	•249	002	2
•147	006	6		•198	023	x	•250	020	=
•148	021	+		•199	014	EX	•251	352	JC
•149	310	RC		•200	003	3	•252	002	2
•150	007	7		•201	020	=	•253	002	2
•151	021	+		•202	022	-	•254	300	ST
•152	310	RC		•203	001	1	•255	004	4
•153	010	8		•204	000	0	•256	202	L 2
•154	020	=		•205	020	=	•257	310	RC
•155	300	ST		•206	300	ST	•258	004	4
•156	003	3		•207	013	S	•259	033	S S
•157	310	RC		•208	023	x	•260	034	PT
•158	012	d		•209	012	d	•261	024	÷
•159	300	ST		•210	002	2	•262	310	RC
				•211	013	S	•263	004	4

315	007		7		367	000		0
316	034	PT			368	300	ST	
317	300	ST			369	004		4
318	004		4		370	300	ST	
319	033	S	S		371	005		5
320	034	PT			372	003		3
321	023		x		373	041	TR	
322	310	RC			374	211	L	9
323	004		4		375	024	+	
324	020	=			376	310	RC	
325	301	ST+			377	005		5
326	010		8		378	020	=	
327	033	S	S		379	300	ST	
328	034	PT			380	004		4
329	023		x		381	022	-	
330	310	RC			382	014	EX	
331	004		4		383	002		2
332	020	=			384	020	=	
333	301	ST+			385	351	JC	
334	011		9		386	010		9
335	000		0		387	030	RT	
336	035	P A			388	210	L	8
337	350	J			389	014	EX	
338	006		6		390	002		2
339	207		L 7		391	300	ST	
340	112	D T			392	004		4
341	035	P A			393	030	RT	
342	310	RC			Evaluation program BLOCK 3			
343	010		8		001	003		3
344	360	B			002	032	I D	
345	011		9		003	310	RC	
346	004		4		004	000		0
347	005		5		005	354	JC	
348	023		x		006	002		2
349	310	RC			007	310	RC	
350	004		4		008	007		7
351	020	=			009	354	JC	
352	300	ST			010	000		0
353	010		8		011	023	x	
354	310	RC			012	012	d	
355	011		9		013	000		0
356	360	B			014	003		3
357	011		9		015	003		3
358	012		d		016	021	+	
359	010		8		017	001		1
360	005		5		018	005		5
361	023		x		019	012	d	
362	310	RC			020	011		9
363	004		4		021	005		5
364	020	=			022	020	=	
365	300	ST			023	360	B	
366	011		9					

BLOCK 3—Cont.

•024	012	d				•127	002	2
•025	300	ST				•128	022	-
•026	004		4			•129	003	3
•027	310	RC				•130	000	0
•028	007		7			•131	300	ST
•029	023	x				•132	004	4
•030	012		d			•133	020	=
•031	000		0			•134	351	JC
•032	003		3			•135	003	3
•033	006		6			•136	310	RC
•034	022	-				•137	002	2
•035	002		2			•138	300	ST
•036	001		1			•139	004	4
•037	012		d			•140	350	J
•038	002		2			•141	004	4
•039	020	=				•142	203	L 3
•040	360	B				•143	300	ST
•041	012		d			•144	005	5
•042	300	ST				•145	350	J
•043	005		5			•146	004	4
•044	000		0			•147	213	L S
•045	300	ST				•148	024	+
•046	007		7			•149	014	EX
•047	200	L	0			•150	002	2
•048	310	RC				•151	022	-
•049	006		6			•152	001	1
•050	354	JC				•153	020	=
•051	001		1			•154	030	RT
•052	061	LG				•155	212	L d
•053	300	ST				•156	300	ST
•054	006		6			•157	000	0
•055	023	x				•158	351	JC
•056	005		5			•159	011	9
•057	000		0			•160	000	0
•058	012		d			•161	030	RT
•059	005		5			•162	211	L 9
•060	022	-				•163	022	-
•061	004		4			•164	014	EX
•062	011		9			•165	002	2
•063	012		d			•166	020	=
•064	003		3			•167	351	JC
•065	020	=				•168	010	0
•066	360	B				•169	310	RC
•067	012		d			•170	000	0
•068	300	ST				•171	030	RT
•069	007		7			•172	210	L 8
•070	310	RC				•173	014	EX
•071	006		6			•174	002	2
•072	023	x				•175	030	RT
•073	004		4			•176	204	L 4
•074	002		2			•177	310	RC
•075	012	d				•178	001	1
•076	010	8						
•077	022	-						
•078	002		2					
•079	007		7					
•080	012		d					
•081	011		9					
•082	020	=						
•083	360	B						
•084	012		d					
•085	300	ST						
•086	006		6					
•087	201	L	1					
•088	310	RC						
•089	004		4					
•090	360	B						
•091	013		S					
•092	300	ST						
•093	004		4					
•094	310	RC						
•095	006		6					
•096	360	B						
•097	013		S					
•098	023		x					
•099	310	RC						
•100	004		4					
•101	020	=						
•102	300	ST						
•103	012		d					
•104	310	RC						
•105	005		5					
•106	360	B						
•107	013		S					
•108	300	ST						
•109	005		5					
•110	310	RC						
•111	007		7					
•112	360	B						
•113	013		S					
•114	023		x					
•115	310	RC						
•116	005		5					
•117	020	=						
•118	300	ST						
•119	013		S					
•120	202	L	2					
•121	000		0					
•122	300	ST						
•123	005		5					
•124	300	ST						
•125	007		7					
•126	310	RC						

BLOCK 3—Cont.

•179	301	ST+		•231	005		5	•284	006		6
•180	004		4	•232	310	RC		•285	110	R	
•181	021	+		•233	004		4	•286	034	PT	
•182	310	RC		•234	023	x		•287	035	P A	
•183	002		2	•235	310	RC		•288	035	P A	
•184	021	+		•236	010		0	•289	310	RC	
•185	310	RC		•237	023	x		•290	007		7
•186	003		3	•238	310	RC		•291	110	R	
•187	020	=		•239	012	d		•292	034	PT	
•188	300	ST		•240	023	x		•293	035	P A	
•189	000		0	•241	012	d		•294	035	P A	
•190	037	CL		•242	002		2	•295	112	D T	
•191	026	(		•243	002		2	•296	002		2
•192	310	RC		•244	007		7	•297	- 033	- S - S	
•193	004		4	•245	020	=		•298	112	D T	
•194	023	x		•246	061	LG		•299	001		1
•195	310	RC		•247	022	-		•300	001		1
•196	010		0	•248	002		2	•301	032	I D	
•197	021	+		•249	020	=		•302	034	PT	
•198	026	(		•250	352	JC		•303	222	DP	2
•199	310	RC		•251	005		5	•304	310	RC	
•200	005		5	•252	024	+		•305	001		1
•201	023	x		•253	003		3	•306	021	+	
•202	006		6	•254	023	x		•307	310	RC	
•203	000		0	•255	026	(		•308	002		2
•204	027	)		•256	310	RC		•309	020	=	
•205	023	x		•257	000		0	•310	300	ST	
•206	310	RC		•258	061	LG		•311	007		7
•207	012	d		•259	023	x		•312	310	RC	
•208	027	)		•260	012	d		•313	001		1
•209	021	+		•261	001		1	•314	110	R	
•210	026	(		•262	021	+		•315	034	PT	
•211	310	RC		•263	012	d		•316	310	RC	
•212	003		3	•264	010		0	•317	002		2
•213	023	x		•265	027	)		•318	110	R	
•214	006		6	•266	023	x		•319	034	PT	
•215	000		0	•267	014	EX		•320	310	RC	
•216	027	)		•268	002		2	•321	007		7
•217	024	+		•269	020	=		•322	110	R	
•218	310	RC		•270	300	ST		•323	034	PT	
•219	000		0	•271	007		7	•324	035	P A	
•220	020	=		•272	205	L	5	•325	310	RC	
•221	300	ST		•273	001		1	•326	003		3
•222	006		6	•274	000		0	•327	110	R	
•223	022	-		•275	032	I D		•328	034	PT	
•224	001		1	•276	034	PT		•329	310	RC	
•225	001		1	•277	220	DP	0	•330	000		0
•226	002		2	•278	310	RC		•331	110	R	
•227	012	d		•279	000		0	•332	034	PT	
•228	005		5	•280	110	R		•333	035	P A	
•229	020	=		•281	034	PT		•334	112	D T	
•230	352	JC		•282	035	P A		•335	001		1
				•283	310	RC		•336	002		2

# BLOCK 3—Cont.

•337	032	I D	
•338	034	PT	
•339	220	DP	0
•340	310	RC	
•341	001		1
•342	021	+	
•343	310	RC	
•344	003		3
•345	020	=	
•346	300	ST	
•347	000		0
•348	000		0
•349	300	ST	
•350	007		7
•351	310	RC	
•352	001		1
•353	023	x	
•354	310	RC	
•355	010		6
•356	023	x	
•357	310	RC	
•358	012	d	
•359	021	+	
•360	026	(	
•361	310	RC	
•362	003		3
•363	023	x	
•364	006		6
•365	000		0
•366	027	)	
•367	024	+	
•368	310	RC	
•369	000		0
•370	020	=	
•371	300	ST	
•372	006		6
•373	004		4
•374	041	TR	

## Evaluation program

### BLOCK 4

•001	004		4
•002	032	I D	
•003	310	RC	
•004	006		6
•005	022	-	
•006	001		1
•007	001		1
•008	002		2
•009	012	d	
•010	005		5
•011	020	=	

•012	352	JC	
•013	000		0
•014	310	RC	
•015	001		1
•016	023	x	
•017	310	RC	
•018	010		6
•019	023	x	
•020	310	RC	
•021	012	d	
•022	023	x	
•023	012	d	
•024	002		2
•025	002		2
•026	007		7
•027	020	=	
•028	061	LG	
•029	022	-	
•030	002		2
•031	020	=	
•032	352	JC	
•033	000		0
•034	024	÷	
•035	003		3
•036	023	x	
•037	026	(	
•038	310	RC	
•039	000		0
•040	061	LG	
•041	023	x	
•042	012	d	
•043	001		1
•044	021	+	
•045	012	d	
•046	010		6
•047	027	)	
•048	023	x	
•049	014	EX	
•050	002		2
•051	020	=	
•052	300	ST	
•053	007		7
•054	200	L	0
•055	310	RC	
•056	000		0
•057	110	R	
•058	034	PT	
•059	310	RC	
•060	006		6
•061	110	R	
•062	034	PT	
•063	310	RC	
•064	007		7

•065	110	R	
•066	034	PT	
•067	035	P A	
•068	112	D T	
•069	001		1
•070	003		3
•071	012	d	
•072	001		1
•073	032	I D	
•074	034	PT	
•075	310	RC	
•076	002		2
•077	301	ST+	
•078	000		0
•079	006		6
•080	000		0
•081	300	ST	
•082	001		1
•083	360	B	
•084	001		1
•085	001		1
•086	003		3
•087	012	d	
•088	002		2
•089	032	I D	
•090	034	PT	
•091	360	B	
•092	002		2
•093	001		1
•094	004		4
•095	012	d	
•096	001		1
•097	032	I D	
•098	034	PT	
•099	002		2
•100	300	ST	
•101	001		1
•102	310	RC	
•103	010		6
•104	320	XC	
•105	011		9
•106	300	ST	
•107	010		6
•108	310	RC	
•109	012		d
•110	320	XC	
•111	013	S	
•112	300	ST	
•113	012	d	
•114	360	B	
•115	001		1
•116	001		1
•117	004		4

BLOCK 4—Cont.

•118	012	d	•170	006	6	•223	034	PT
•119	002	2	•171	023	x	•224	035	P A
•120	032	I D	•172	310	RC	•225	030	RT
•121	034	PT	•173	012	d	•226	202	L 2
•122	360	B	•174	027	)	•227	310	RC
•123	002	2	•175	020	=	•228	006	6
•124	002	2	•176	300	ST	•229	023	x
•125	033	S S	•177	002	2	•230	012	d
•126	201	L 1	•178	203	L 3	•231	002	2
•127	310	RC	•179	310	RC	•232	002	2
•128	005	5	•180	006	6	•233	007	7
•129	023	x	•181	024	+	•234	020	=
•130	310	RC	•182	026	(	•235	110	R
•131	001	1	•183	310	RC	•236	034	PT
•132	021	+	•184	004	4	•237	035	P A
•133	026	(	•185	021	+	•238	310	RC
•134	310	RC	•186	310	RC	•239	012	d
•135	004	4	•187	005	5	•240	360	B
•136	023	x	•188	027	)	•241	011	9
•137	310	RC	•189	020	=	•242	360	B
•138	010	8	•190	110	R	•243	010	8
•139	027	)	•191	034	PT	•244	352	JC
•140	020	=	•192	035	P A	•245	006	6
•141	300	ST	•193	310	RC	•246	310	RC
•142	006	6	•194	012	d	•247	002	2
•143	023	x	•195	360	B	•248	023	x
•144	310	RC	•196	011	9	•249	310	RC
•145	012	d	•197	360	B	•250	000	0
•146	021	+	•198	010	8	•251	020	=
•147	026	(	•199	352	JC	•252	360	B
•148	310	RC	•200	004	4	•253	011	9
•149	003	3	•201	310	RC	•254	350	J
•150	023	x	•202	002	2	•255	007	7
•151	310	RC	•203	023	x	•256	206	L 6
•152	001	1	•204	026	(	•257	035	P A
•153	027	)	•205	310	RC	•258	207	L 7
•154	020	=	•206	004	4	•259	035	P A
•155	024	÷	•207	021	+	•260	310	RC
•156	310	RC	•208	310	RC	•261	007	7
•157	000	0	•209	005	5	•262	023	x
•158	020	=	•210	027	)	•263	310	RC
•159	300	ST	•211	020	=	•264	000	0
•160	007	7	•212	360	B	•265	023	x
•161	360	B	•213	011	9	•266	012	d
•162	010	8	•214	350	J	•267	002	2
•163	352	JC	•215	005	5	•268	002	2
•164	003	3	•216	204	L 4	•269	007	7
•165	310	RC	•217	035	P A	•270	020	=
•166	007	7	•218	205	L 5	•271	110	R
•167	024	+	•219	035	P A	•272	034	PT
•168	026	(	•220	310	RC	•273	035	P A
•169	310	RC	•221	007	7	•274	112	D T
			•222	110	R	•275	030	RT

BLOCK 4—Cont.

•276	210	L	0
•277	310	RC	
•278	007		7
•279	022	-	
•280	310	RC	
•281	001		1
•282	020	=	
•283	030	RT	
•284	211	L	0
•285	013	S	
•286	021	+	
•287	001		1
•288	023	x	
•289	014	EX	
•290	002		2
•291	020	=	
•292	110	R	
•293	034	PT	
•294	030	RT	

Combining ratings

BLOCK 5

•001	005		5
•002	032	I D	
•003	035	P A	
•004	112	D T	
•005	004		4
•006	003		3
•007	015	/	
•008	001		1
•009	015	/	
•010	005		5
•011	012	d	
•012	000		0
•013	015	/	
•014	034	PT	
•015	112	D T	
•016	035	P A	
•017	137	CA	
•018	000		0
•019	220	DP	0
•020	201	L	1
•021	033	S S	
•022	354	JC	
•023	002		2
•024	300	ST	
•025	010		0
•026	034	PT	
•027	033	S S	
•028	300	ST	
•029	011		9
•030	034	PT	

•031	033	S S	
•032	034	PT	
•033	035	P A	
•034	354	JC	
•035	001		1
•036	023	x	
•037	012	d	
•038	000		0
•039	003		3
•040	024	+	
•041	026	(	
•042	310	RC	
•043	010		0
•044	061	LG	
•045	023	x	
•046	012	d	
•047	001		1
•048	021	+	
•049	012	d	
•050	010		0
•051	027	)	
•052	020	=	
•053	161	L-1	
•054	301	ST+	
•055	001		1
•056	310	RC	
•057	010		0
•058	301	ST+	
•059	002		2
•060	023	x	
•061	310	RC	
•062	011		0
•063	020	=	
•064	301	ST+	
•065	003		3
•066	000		0
•067	350	J	
•068	001		1
•069	202	L	2
•070	035	P A	
•071	112	D T	
•072	035	P A	
•073	001		1
•074	000		0
•075	012	d	
•076	011		0
•077	032	I D	
•078	034	PT	
•079	310	RC	
•080	002		2
•081	110	R	
•082	034	PT	
•083	035	P A	

•084	354	JC	
•085	004		4
•086	310	RC	
•087	003		3
•088	024	+	
•089	310	RC	
•090	002		2
•091	020	=	
•092	110	R	
•093	300	ST	
•094	006		6
•095	310	RC	
•096	001		1
•097	061	LG	
•098	024	+	
•099	012	d	
•100	000		0
•101	003		3
•102	023	x	
•103	026	(	
•104	310	RC	
•105	002		2
•106	061	LG	
•107	023	x	
•108	012	d	
•109	001		1
•110	021	+	
•111	012	d	
•112	010		0
•113	027	)	
•114	020	=	
•115	351	JC	
•116	003		3
•117	000		0
•118	203	L	3
•119	110	R	
•120	300	ST	
•121	007		7
•122	204	L	4
•123	310	RC	
•124	306		6
•125	034	PT	
•126	035	P A	
•127	035	P A	
•128	310	RC	
•129	007		7
•130	034	PT	
•131	035	P A	
•132	112	D T	
•133	035	P A	
•134	035	P A	
•135	350	J	
•136	033	S S	

## Appendix E

### Manual Calculations

The worksheets in this appendix allow evaluation of an animal lot manually--that is, without aid of a programmable calculator. No worksheet is provided for the screening or the preliminary evaluation (see Appendix A for the formulas) nor to combine animal lot ratings. The latter is done by summing total runoff and loading from each animal lot or portion that is a pollution hazard (that is, whose COD concentration exceeds 112.5 ppm) before calculating  $F_1$  and  $F_2$  to obtain the animal lot rating.

#### Appendix E-1 User-Oriented Procedure ..... Page 58

This set of worksheets is designed to make it easy for the user to calculate the rating and other outputs of the model.

#### Appendix E-2 Calculator-Oriented Procedure ..... Page 65

The algorithms used here are identical to those used by the programmable calculators. This set of worksheets is designed to make it easy for the programmer to modify the programs in Appendix D to fit conditions in other States, and to run on other calculators or on computers.

## User-Oriented Manual Calculation Procedure

Final calculations can also be completed manually by following the remaining steps.

Feedlot Evaluation System. Operator \_\_\_\_\_

Step 10. Calculate runoff volumes using Figure 1.  
Equations [1] and [2] may also be used.

$$S = \frac{1000}{CN} - 10 \quad [1]$$

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad [2]$$

CN = soil cover complex number (from Step 6)

P = design rainfall, inches (from Step 3)

Q = runoff, inches

	CN	:	S	:	P	:	Q	X	Area (from Step 4)	= Vol. (acre-in)	
Area 1	_____		_____		_____		_____	X	_____	= Total Vol <sub>1</sub>	= _____ acre-in*
2 <sub>a</sub>	_____		_____		_____		_____	X	_____	= _____	
2 <sub>b</sub>	_____		_____		_____		_____	X	_____	= _____	
2 <sub>r</sub> (roof)	100		0		_____		_____	X	_____	= _____	
										Total Vol <sub>2</sub>	= _____ acre-in*
										Total Vol <sub>1+2</sub>	= _____ acre-in*
3	_____		_____		_____		_____	X	_____	= _____	
										Total Vol <sub>3</sub>	= _____ acre-in*
										Total Vol <sub>1+2+3</sub>	= _____ acre-in* (33)

---

\* Note: Starred items appear in computer printout of additional information available.

Step. 11. Calculate equivalent animal units (EAU) from information in Step 8.

Animal type	No. of animals (Step 8)	X	Factor = (Table 6) <sup>1</sup>	=	EAU
COD: _____	_____	X	_____	=	_____
_____	_____	X	_____	=	_____
_____	_____	X	_____	=	_____
_____	_____	X	_____	=	_____
					Total = _____ EAU
P: _____	_____	X	_____	=	_____
_____	_____	X	_____	=	_____
_____	_____	X	_____	=	_____
_____	_____	X	_____	=	_____
					Total = _____ EAU

Step 12. Calculate animal unit density (AUD) and % manure pack.

EAU	÷	Area 1	=	AUD
(Step 11)		(Step 4)		
COD: _____	÷	_____	=	_____
		_____		
P: _____	÷	_____	=	_____

-- if AUD < 100, % manure pack = AUD

-- if AUD ≥ 100, % manure pack = 100

Manure pack (COD) = \_\_\_\_\_%

Manure pack (P) = \_\_\_\_\_%

<sup>1</sup>Appendix B, p. 28.

Step 13. Calculate concentration of COD and P in runoff at feedlot edge.

a) if  $Vol_2 \leq 30$

	% manure pack (Step 12)	X	Factor	=	Concentration
COD:	_____	X	45	=	_____ mg/l*
P:	_____	X	0.85	=	_____ mg/l*

b) if  $Vol_2 > 30$

$$\left[ \frac{\% \text{ manure pack} \times \text{factor}_1 \times (Vol_1 + 30) + Vol_2 - 30 \times \text{factor}_2}{Vol_{1+2}} \right] = \text{Concentration}$$
  
(Step 12)

COD: [ \_\_\_\_\_ X 45 X ( \_\_\_\_\_ + 30) + ( \_\_\_\_\_ - 30) X 60 ] / \_\_\_\_\_ = \_\_\_\_\_ mg/l\*

P: [ \_\_\_\_\_ X 0.85 X ( \_\_\_\_\_ + 30) + ( \_\_\_\_\_ - 30) X 2 ] / \_\_\_\_\_ = \_\_\_\_\_ mg/l\*

Step 14. Calculate mass load of pollutants in runoff at feedlot edge.

	Concentration	X	$Vol_{1+2}$ (Step 10)	X	Conversion factor <sup>2</sup>	=	Mass load
COD:	_____	X	_____	X	0.227	=	_____ lb*
P:	_____	X	_____	X	0.227	=	_____ lb*

Step 15. Determine velocity through each buffer section using figure 2. Equation [3] may also be used.

$$\log v = 0.5 \log s - c \quad [3]$$

v = runoff velocity, ft/sec

s = slope, % (Step 7)

c = surface condition constant (from Table 4 or Step 7)<sup>3</sup>

$$2 \left( \frac{43,560 \text{ ft}^2}{A} \right) \left( \frac{\text{ft}}{12 \text{ in}} \right) \left( \frac{1}{10^6} \right) \left( \frac{62.4 \text{ lb}}{\text{ft}^3} \right) = 0.227$$

<sup>3</sup>Table 4, p. 23 or Step 7, p. 24, Appendix B.

Note<sub>1</sub> : If the buffer section is a grass waterway (c from table 4 or Step 7 = 1.0),<sup>3</sup> use a value of c = -0.18 in equation [3].

Note<sub>2</sub> : If the buffer section is overland flow and v > 2.0, use v = 2.0.

Section a, velocity = \_\_\_\_\_ ft/sec

Section b, velocity = \_\_\_\_\_ ft/sec

velocity = \_\_\_\_\_ ft/sec

Step 16. Calculate the time of contact ( $T_c$ ) in the buffer. Keep  $T_c$  in grass waterways separate from  $T_c$  in overland flow.

	Distance, L (Step 7)	+	Runoff velocity (Step 15)	=	Time of contact, $T_c$	
Section a	_____	+	_____	=	_____	sec
Section b	_____	+	_____	=	_____	sec
	_____	+	_____	=	_____	sec

Total  $T_c$  (overland flow) = \_\_\_\_\_ sec

Total  $T_c$  (grass waterway) = \_\_\_\_\_ sec

Step 17. Calculate percent reduction in pollutant strength due to buffer effects using figures 3 and 4. Equations [4-7] may also be used.

-- if overland flow

$$\text{COD: } D_c = -27.9 + 42.8 \log T_c \quad [4]$$

$$\text{P: } D_p = -49.3 + 50.5 \log T_c \quad [5]$$

-- if grass waterway

$$\text{COD: } D_c = 15.95 + 0.033 T_c \quad [6]$$

$$\text{P: } D_p = -21.2 + 0.036 T_c \quad [7]$$

D = decrease in pollutant strength, %

$T_c$  = time of contact, sec. (Step 16)

Feedlot Evaluation System. Operator \_\_\_\_\_

Overland flow (OF) COD decrease = \_\_\_\_\_%

P decrease = \_\_\_\_\_%

Grass waterway (GW) COD decrease = \_\_\_\_\_%

P decrease = \_\_\_\_\_%

Note: If decrease > 100%, use decrease = 100%.

If decrease < 0%, use decrease = 0%.

$$\left[ 1 - \left( 1 - \frac{\% \text{ decrease (OF)}}{100} \right) \times \left( 1 - \frac{\% \text{ decrease (GW)}}{100} \right) \right] \times 100 = \% \text{ reduction due to the buffer effects}$$

COD:  $\left[ 1 - \frac{\% \text{ decrease (OF)}}{100} \times \left( 1 - \frac{\% \text{ decrease (GW)}}{100} \right) \right] \times 100 = \text{_____}\%$

P:  $\left[ 1 - \frac{\% \text{ decrease (OF)}}{100} \times \left( 1 - \frac{\% \text{ decrease (GW)}}{100} \right) \right] \times 100 = \text{_____}\%$

Step 18. Calculate reduced pollutant strength remaining after infiltration, settling, adsorption, etc., in buffer.

$$\begin{array}{l} \text{Concentration} \\ \text{at feedlot edge} \\ \text{(Step 13)} \end{array} \times \left[ 1 - \frac{\% \text{ reduction (from Step 17)}}{100} \right] = \text{Reduced concentration}$$

COD: \_\_\_\_\_ X \_\_\_\_\_ = \_\_\_\_\_ mg/l

P: \_\_\_\_\_ X \_\_\_\_\_ = \_\_\_\_\_ mg/l

Step 19. Calculate reduced pollutant strength due to dilution of feedlot runoff with runoff from the buffer and adjacent areas.

$$\left[ \begin{array}{l} \text{Reduced} \\ \text{concentration} \\ \text{(Step 18)} \end{array} \times \text{Vol}_{1+2} \right] + \left[ \begin{array}{l} \text{Vol}_3 \\ \text{(Step 10)} \end{array} \times \text{factor} \right] / \text{Vol}_{1+2+3} = \text{Final concentration}$$

COD:  $\left[ \left( \frac{\text{Reduced concentration (Step 18)} \times \text{Vol}_{1+2}}{\text{Vol}_{1+2+3}} \right) + \left( \frac{\text{Vol}_3 \times \text{factor}}{\text{Vol}_{1+2+3}} \right) \right] = \text{_____ mg/l}^*(34)$

P:  $\left[ \left( \frac{\text{Reduced concentration (Step 18)} \times \text{Vol}_{1+2}}{\text{Vol}_{1+2+3}} \right) + \left( \frac{\text{Vol}_3 \times \text{factor}}{\text{Vol}_{1+2+3}} \right) \right] = \text{_____ mg/l}^*$

Step 20. Calculate the percent reduction in pollutant strength due to dilution.

$$\left[ \frac{\text{Reduced concentration (Step 18)} - \text{Final concentration (Step 19)}}{\text{Reduced concentration (Step 18)}} \right] \times 100 = \% \text{ reduction due to dilution}$$

COD:  $\left[ \frac{\text{Reduced concentration (Step 18)} - \text{Final concentration (Step 19)}}{\text{Reduced concentration (Step 18)}} \right] \times 100 = \text{_____}\%$

P:  $\left[ \frac{\text{Reduced concentration (Step 18)} - \text{Final concentration (Step 19)}}{\text{Reduced concentration (Step 18)}} \right] \times 100 = \text{_____}\%$

Feedlot Evaluation System. Operator \_\_\_\_\_

Step 21. Calculate final pollutant load

$$\begin{array}{ccccc} \text{Final concentration} & \times & \text{Vol}_{1+2+3} & \times & \text{Conversion factor} = \text{Mass load} \\ \text{(Step 19)} & & \text{(Step 10)} & & \end{array}$$

$$\text{COD: } \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} = \underline{\hspace{2cm}} \text{ lb}^*$$

$$\text{P: } \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \times 0.227 = \underline{\hspace{2cm}} \text{ lb}^*$$

Step 22. Calculate the percent change in pollutant load due to feedlot runoff mixing with runoff from the buffer and adjacent areas.

$$100 \left[ \frac{\text{Load at lot edge}}{\text{(Step 14)}} \times \left( 1 - \frac{\% \text{ reduction}}{100} \right) - \frac{\text{Final load}}{\text{(Step 21)}} \right] / \left[ \frac{\text{Load at lot edge}}{\text{(Step 14)}} \times \left( 1 - \frac{\% \text{ reduction}}{100} \right) \right] = \frac{\% \text{ change due to mixing}}{\text{(Step 17)}}$$

$$\text{COD: } 100 \left[ \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} - \underline{\hspace{2cm}} \right] / \left[ \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \right] = \underline{\hspace{2cm}} \%$$

$$\text{P: } 100 \left[ \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} - \underline{\hspace{2cm}} \right] / \left[ \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \right] = \underline{\hspace{2cm}} \%$$

Step 23. Calculate mass load of COD for rating feedlot by either method a or b.

a) if  $\text{Vol}_2 \leq 30$

$$\begin{array}{ccccc} \text{Manure pack} & \times & \text{Vol}_{1+2} & \times & \text{factor}^4 \times \left[ 1 - \frac{\% \text{ reduction}}{100} \right] = \text{Mass load} \\ \text{(Step 12)} & & \text{(Step 10)} & & \text{(Step 17)} \end{array}$$

$$\underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \times 10.215 \times \underline{\hspace{2cm}} = \underline{\hspace{2cm}} \text{ lb COD}$$

b) if  $\text{Vol}_2 > 30$

$$\begin{array}{ccccc} \text{Manure pack} & \times & (\text{Vol}_1 + 30) & \times & 10.215 \times \left[ 1 - \frac{\% \text{ reduction}}{100} \right] = \text{Mass load} \\ & & & & \text{(Step 17)} \end{array}$$

$$\underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \times 10.215 \times \underline{\hspace{2cm}} = \underline{\hspace{2cm}} \text{ lb COD}$$

If the final COD concentration  $\leq 112.5$  mg/l, no further calculation is necessary and the animal lot can be considered to pose no surface water pollution hazard.

If the final COD concentration  $> 112.5$  mg/l, continue calculation to determine a numerical rating of the animal lot as follows:

$$\underline{\hspace{2cm}}^4 4500/100 \times 0.227 = 10.215.$$

Step 24. Calculate a rating factor for the animal lot using equation [8].

$$F_1 = \frac{[\log \text{COD}_{\text{mass load}}]^{-2}}{3} \quad [8]$$

(Step 23)

$F_1 =$  \_\_\_\_\_

Step 25. Calculate a weighting factor using equation [9].

$$F_2 = 0.8 + 0.1 \log \text{Vol}_{1+2+3} \quad [9]$$

(Step 10)

$F_2 =$  \_\_\_\_\_

Step 26. Calculate final rating for animal lot.

$F_1$ (Step 24)	x	$F_2$ (Step 25)	x	100	
					= Animal lot rating
					(round off to nearest whole number)
_____	x	_____	x	100	= _____ (35)

Results of evaluation.

Surface water:

Total volume of runoff at the discharge point (Step 10) \_\_\_\_\_ acre-in (33)

COD concentration at the discharge point (Step 19) \_\_\_\_\_ mg/l (34)

Description of discharge point and/or name of receiving water if applicable

 \_\_\_\_\_  
 \_\_\_\_\_
Animal lot rating for surface-water pollution  
(0 = no hazard, 100 = very severe hazard) (Step 26) \_\_\_\_\_ (35)

Ground water: (from line 32) (0 = minor hazard, 5 = very severe hazard) (Step 9) \_\_\_\_\_ (36)

Additional comments:

 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Prepared by \_\_\_\_\_ Date \_\_\_\_\_

## Calculator-Oriented Manual Calculation Procedure

Final calculations can also be completed manually by following the remaining steps.

- Step 11. Calculate runoff volumes using figure 1. Equations [1] and [2] may also be used.

$$S = \frac{1000}{CN} - 10 \quad [1]$$

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad [2]$$

CN = soil cover complex number (Step 6)

P = design rainfall, inches (Step 3)

Q = runoff, inches

Area	CN	S	P	Q	x	Area (Step 4)	= Volume
1	_____	_____	_____	_____	x	_____	= Vol <sub>1</sub> = _____ acre-in
2 <sub>a</sub>	_____	_____	"	_____	x	_____	= _____
2 <sub>b</sub>	_____	_____	"	_____	x	_____	= _____
2 <sub>r</sub> (roof)	_____	_____	"	_____	x	_____	= _____
							Total = Vol <sub>2</sub> = _____ acre-in
3 <sub>a</sub>	_____	_____	"	_____	x	_____	= _____
3 <sub>b</sub>	_____	_____	"	_____	x	_____	= _____
3 <sub>c</sub>	_____	_____	"	_____	x	_____	= _____
3 <sub>d</sub>	_____	_____	"	_____	x	_____	= _____
							Total = Vol <sub>3</sub> = _____ acre-in

- Step 12. Calculate time of contact in the buffer. Repeat Steps 12a-12d for each buffer section.

- (a) Check the value of c. If c = 1.0, this is a grass waterway. This fact affects the value of c and the maximum velocity.
- (b) Determine velocity of flow through buffer using figure 2. Equation [3] may also be used.

$$\log v = 0.5 \log s - c \quad [3]$$

where v = runoff velocity, ft/sec  
s = slope, % (Step 7)  
c = surface condition constant  
(from Table 4 or Step 7,<sup>3</sup>  
except set c = -0.18 for  
a grass waterway).

(c) Record velocity below, except that if this is overland flow, and if the calculated velocity exceeds 2.0, use  $v = 2.0$ .

(d) Calculate time of contact.

$$\begin{array}{rcl} \text{Distance, L} & \div & \text{Runoff velocity} = \text{Time of} \\ \text{(Step 7)} & & \text{(Step 12c)} \quad \text{contact, } T_c \\ \hline & \div & = \quad \text{min} \end{array}$$

(e) Add up times of contact in all buffer sections.

Overland flow:	Total $T_c$
_____ + _____ + _____ + _____ + _____ + _____	= _____ min
Grass waterway:	Total $T_c$
_____ + _____ + _____ + _____ + _____ + _____	= _____ min

Step 13. Calculate equivalent animal units (EAU) from information in Step 8.

Animal type	Number of animals	x	Factor (Table 6)	=	EAU
COD: _____	_____	x	_____	=	_____
_____	_____	x	_____	=	_____
_____	_____	x	_____	=	_____
					Total = _____ EAU
P: _____	_____	x	_____	=	_____
_____	_____	x	_____	=	_____
_____	_____	x	_____	=	_____
					Total = _____ EAU

Step 14. Calculate animal unit density (AUD) and % manure pack.

EAU (Step 13)	÷	Area 1 (Step 4)	=	AUD
COD: _____	÷	_____	=	_____
P: _____	÷	_____	=	_____

-- If  $AUD < 100$ , % manure pack = AUD.  
 -- If  $AUD \geq 100$ , % manure pack = 100.

Manure pack (COD) = _____
Manure pack (P) = _____

Step 15. Calculate concentration of COD and P in undiluted feedlot runoff.

	Manure Pack (Step 14)	x	factor	=	concentration
COD:	_____	x	45	=	_____ mg/ℓ
P:	_____	x	0.85	=	_____ mg/ℓ

Step 16. Calculate percent decrease in pollutant strength using figures 3 & 4. Equations [4-7] may also be used.

-- if overland flow,

$$\text{COD : D} = -27.9 + 42.8 \log T_c \quad [4]$$

$$\text{P : D} = -49.3 + 50.5 \log T_c \quad [5]$$

-- if grass waterway,

$$\text{COD : D} = 15.95 + 0.033 T_c \quad [6]$$

$$\text{P : D} = -21.2 + 0.036 T_c \quad [7]$$

D = decrease in pollutant strength, %  
 $T_c$  = time of contact, seconds (Step 12e)

Overland flow (OF) COD decrease = \_\_\_\_\_ %

P decrease = \_\_\_\_\_ %

Grass waterway (GW) COD decrease = \_\_\_\_\_ %

P decrease = \_\_\_\_\_ %

Note: If decrease > 100%, use decrease = 100%.  
 If decrease < 0%, use decrease = 0%.

Step 17. Calculate the proportion of pollutant strength remaining after infiltration, settling, and adsorption in buffer using information from Step 16.

$$\left[ 1 - \frac{\% \text{ decrease (GW)}}{100} \right] \times \left[ 1 - \frac{\% \text{ decrease (OF)}}{100} \right] = \text{Remaining proportion of strength}$$

$$\text{COD: } (1 - \frac{\text{_____}}{100}) \times (1 - \frac{\text{_____}}{100}) = \text{_____}$$

$$\text{P: } (1 - \frac{\text{_____}}{100}) \times (1 - \frac{\text{_____}}{100}) = \text{_____}$$

(Note: The proportion of strength remaining must be in the range from zero to 1.)

Step 18. Calculate "transformed" volumes, for use in all subsequent calculations, from Volume 1 and Volume 2 (calculated in Step 11). Use either Step 18a or Step 18b, and cross out the part not used.

Transformed Volume 1 (Vol 1T) = volume of runoff from feedlot and Area 2 whose concentration is the same as the concentration of undiluted feedlot runoff (this concentration was determined in Step 15).

Transformed Volume 2 (Vol 2T) = volume of runoff from Area 2, which does not flush pollutants from the feedlot surface but serves to dilute that runoff.

(a) If Volume 2  $\leq$  30 acre-in:

$$\text{Volume 1} + \text{Volume 2} = \text{Vol 1T}$$

$$\underline{\hspace{2cm}} + \underline{\hspace{2cm}} = \underline{\hspace{2cm}} = \text{Vol 1T}$$

$$\text{Volume 2T equals zero.} \quad 0 = \text{Vol 2T}$$

(b) If Volume 2  $>$  30 acre-in:

$$\text{Volume 1} + 30 = \text{Vol 1T}$$

$$\underline{\hspace{2cm}} + 30 = \underline{\hspace{2cm}} = \text{Vol 1T}$$

$$\text{Volume 2} - 30 = \text{Vol 2T}$$

$$\underline{\hspace{2cm}} - 30 = \underline{\hspace{2cm}} = \text{Vol 2T}$$

Step 19. Calculate other needed volumes.

$$\begin{array}{rcl} \text{Volume 1T} & + & \text{Volume 2T} \\ \text{(Step 18)} & & \text{(Step 18)} \end{array} = \begin{array}{l} \text{Volume of runoff} \\ \text{from feedlot} \end{array}$$

$$\underline{\hspace{2cm}} + \underline{\hspace{2cm}} = \underline{\hspace{2cm}}$$

$$\begin{array}{rcl} \text{Volume of run-} & & \\ \text{off from feed-} & + & \text{Volume 3} \\ \text{lot (from line} & & \text{(Step 11)} \\ \text{above)} & & \end{array} = \text{Total volume}$$

$$\underline{\hspace{2cm}} + \underline{\hspace{2cm}} = \underline{\hspace{2cm}} \quad (\text{line 33})$$

Step 20. Calculate amount of pollutants in runoff at feedlot edge.

$$\left[ \begin{array}{l} \text{Volume 1T x} \\ \text{(Step 18)} \end{array} \begin{array}{l} \text{Concentration} \\ \text{of undiluted} \\ \text{runoff} \\ \text{(Step 15)} \end{array} \right] + \left[ \begin{array}{l} \text{Volume 2T x} \\ \text{(Step 18)} \end{array} \begin{array}{l} \text{Background} \\ \text{concentration} \end{array} \right] = \text{Amount}$$

$$\text{COD:} \quad \left( \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \right) + \left( \underline{\hspace{2cm}} \times 60 \right) = \underline{\hspace{2cm}}$$

$$\text{P:} \quad \left( \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \right) + \left( \underline{\hspace{2cm}} \times 2 \right) = \underline{\hspace{2cm}}$$

Step 21. Calculate concentration of pollutants in runoff at feedlot edge.<sup>5</sup>

$$\begin{array}{rclcl} \text{Amount} & \div & \text{Volume of runoff} & = & \text{Concentration} \\ \text{(Step 20)} & & \text{from feedlot} & & \\ & & \text{(Step 19)} & & \\ \text{COD: } & \underline{\hspace{2cm}} & \div & \underline{\hspace{2cm}} & = \underline{\hspace{2cm}} \text{ ppm} \\ \text{P: } & \underline{\hspace{2cm}} & \div & \underline{\hspace{2cm}} & = \underline{\hspace{2cm}} \text{ ppm} \end{array}$$

Step 22. Calculate mass of pollutants in runoff at feedlot edge.

$$\begin{array}{rclcl} \text{Amount} & & \times \text{Conversion factor} & = & \text{Mass}^6 \\ \text{(Step 20)} & & & & \\ \text{COD: } & \underline{\hspace{2cm}} & \times & 0.227 & = \underline{\hspace{2cm}} \text{ lb} \\ \text{P: } & \underline{\hspace{2cm}} & \times & 0.227 & = \underline{\hspace{2cm}} \text{ lb} \end{array}$$

Step 23. Calculate amount of pollutants from feedlot edge runoff delivered to discharge point.

$$\begin{array}{rclcl} \text{Amount} & \times & \text{Remaining pollutant strength} & = & \text{Amount} \\ \text{(Step 20)} & & \text{(Step 17)} & & \\ \text{COD: } & \underline{\hspace{2cm}} & \times & \underline{\hspace{2cm}} & = \underline{\hspace{2cm}} \\ \text{P: } & \underline{\hspace{2cm}} & \times & \underline{\hspace{2cm}} & = \underline{\hspace{2cm}} \end{array}$$

Step 24. Calculate amount of pollutants from Area 3 delivered to discharge point.

$$\begin{array}{rclcl} \text{Volume 3} & \times & \text{Background} & = & \text{Amount} \\ \text{(Step 11)} & & \text{concentration} & & \\ \text{COD: } & \underline{\hspace{2cm}} & \times & 60 & = \underline{\hspace{2cm}} \\ \text{P: } & \underline{\hspace{2cm}} & \times & 2 & = \underline{\hspace{2cm}} \end{array}$$

<sup>5</sup>All the results of Steps 21, 22, 26, 28, and 31 may be printed by the programmable calculator. If such additional information on pollutant loadings is not needed, Steps 21, 22, and 27-31, as well as those portions of Steps 13-17, 20, and 23-26 pertaining to P, may all be omitted.

<sup>6</sup>The conversion factor used to convert amount of a pollutant (units: parts per million x acre-inches) to mass (units: pounds) is derived as follows:

1 acre-inch = 3,630 cubic feet  
1 acre-inch water weighs approximately 226,512 pounds  
1 part per million (pollutant loading) in an acre-inch water weighs:

$$\frac{226,512}{1,000,000} = 0.227 \text{ pound} = 1 \text{ ppm-acre-inch}$$

Step 25. Calculate total amount of pollutants delivered to discharge point.

	Amount from feedlot edge runoff (Step 23)	+	Amount from Area 3 (Step 24)	=	Total amount
COD:	_____	+	_____	=	_____
P:	_____	+	_____	=	_____

Step 26. Calculate concentration of pollutants delivered to discharge point.

	Amount (Step 25)	÷	Total volume (Step 19)	=	Concentration
COD:	_____	÷	_____	=	_____ ppm (line 34)
P:	_____	÷	_____	=	_____ ppm

Step 27. Check for artificially low COD and P levels.<sup>7</sup>

COD: If final COD concentration (Step 26) is less than 60.0, mark out the COD calculations in Steps 29 & 30, and write the word "blank" in the third and fifth lines of Step 31.

P: If final P concentration (Step 26) is less than 2.0, mark out the P calculations in Steps 29 & 30, and write the word "blank" in the fourth and sixth lines of Step 31.

Note: If either value is above the limit (60 or 2, respectively), you have taken no action as a result of performing the check.

Step 28. Calculate mass of pollutants delivered to discharge point.

	Amount (Step 25)	x	Conversion factor	=	Mass
COD:	_____	x	0.227	=	_____ lb
P:	_____	x	0.227	=	_____ lb

Step 29. Calculate proportion of pollutant concentration remaining after considering effect of dilution.

Concentration of pollutants delivered to discharge point (Step 26)	÷	<div style="display: inline-block; vertical-align: middle;"> <div style="border-left: 1px solid black; border-right: 1px solid black; padding: 0 5px;"> Concentration of pollutants in runoff at feed- lot edge (Step 21) </div> <div style="padding: 0 5px;"> x pollutant strength (Step 17) </div> </div>	=	Proportion remaining
--	---	---	---	-------------------------

<sup>7</sup>This check has not been incorporated in the calculator programs.

$$\text{COD: } \underline{\hspace{2cm}} \div \left( \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \right) = \underline{\hspace{2cm}}$$

$$\text{P: } \underline{\hspace{2cm}} \div \left( \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \right) = \underline{\hspace{2cm}}$$

Step 30. Calculate proportion of pollutant mass loading remaining after considering effect of dilution.

$$\begin{array}{l} \text{Mass of pollutants} \\ \text{delivered to dis-} \\ \text{charge point} \\ \text{(Step 28)} \end{array} \div \left[ \begin{array}{l} \text{Mass of pollutants} \\ \text{in runoff at} \\ \text{feedlot edge} \\ \text{(Step 22)} \end{array} \times \begin{array}{l} \text{Remaining} \\ \text{pollutant} \\ \text{strength} \\ \text{(Step 17)} \end{array} \right] = \text{Proportion} \\ \text{remaining}$$

$$\text{COD: } \underline{\hspace{2cm}} \div \left( \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \right) = \underline{\hspace{2cm}}$$

$$\text{P: } \underline{\hspace{2cm}} \div \left( \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \right) = \underline{\hspace{2cm}}$$

Step 31. Convert proportion of pollutant remaining (COD and P values from Steps 17, 29, and 30) to percentage reductions in pollutant concentration or loading, using Equation [8]:

$$\% \text{ reduction} = 100 (1 - \text{proportion remaining}) \quad [8]$$

From Step 17:	COD:	$100 (1 - \underline{\hspace{1cm}}) = \underline{\hspace{1cm}}\%$	} These values cannot be less than zero.
	P:	$100 (1 - \underline{\hspace{1cm}}) = \underline{\hspace{1cm}}\%$	
From Step 29:	COD:	$100 (1 - \underline{\hspace{1cm}}) = \underline{\hspace{1cm}}\%$	
	P:	$100 (1 - \underline{\hspace{1cm}}) = \underline{\hspace{1cm}}\%$	
From Step 30:	COD:	$100 (1 - \underline{\hspace{1cm}}) = \underline{\hspace{1cm}}\%$	
	P:	$100 (1 - \underline{\hspace{1cm}}) = \underline{\hspace{1cm}}\%$	

Step 32. Check for compliance with State standards.

If concentration of COD delivered to discharge point (from Step 26) is less than 112.5 ppm, rating is zero, no further calculations are needed, and evaluation of this feedlot is complete. Enter "0" in Step 38.

Step 33. If feedlot is not in compliance with standards, continue with this step and calculate COD mass loading for computation of rating. Use these factors:

Factor a = COD concentration of undiluted feedlot runoff (from Step 15)

Factor b = Proportion of COD remaining after buffer effects (from Step 17)

$$\begin{array}{l} \text{Factor a} \times \text{Factor b} \times \text{Volume 1T} \times \text{Conversion} = \text{COD mass for} \\ \text{(Step 15)} \quad \text{(Step 17)} \quad \text{(Step 18)} \quad \text{factor} \quad \text{rating} \end{array}$$

$$\underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \times 0.227 = \underline{\hspace{2cm}}$$

Step 34. Check for miniscule COD mass.

If COD mass for rating (from Step 33) is less than 101 lbs., rating is zero, no further calculations are needed, and evaluation of this feedlot is complete. Enter "0" in Step 38.

Step 35. If COD mass loading is not miniscule, continue with this step and calculate a COD factor for rating using Equation [9], where the mass for rating was determined in Step 33.

$$F_1 = \frac{\text{Log (mass for rating)} - 2}{3} \quad [9]$$

$$F_1 = \underline{\hspace{2cm}}$$

Step 36. Calculate a weighting factor for rating using Equation [10], where the total volume was determined in Step 19.

$$F_2 = 0.8 + 0.1 \log (\text{total volume}) \quad [10]$$

$$F_2 = \underline{\hspace{2cm}}$$

Step 37. Calculate preliminary rating:

$$\frac{F_1}{(\text{Step 35})} \times \frac{F_2}{(\text{Step 36})} \times 100 = \text{Preliminary rating}$$
$$\underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \times 100 = \underline{\hspace{2cm}}$$

Step 38. Calculate final rating.

Enter "0" from Step 32 or Step 34, or round the preliminary rating (Step 37) to the nearest whole number and enter here.

Rating

           (line 35)

Step 39. Calculate rating for a diverted lot.

(a) Vol 1T = Volume 1 (Step 11): Vol 1T =           

Vol 2T = zero: Vol 2T = 0

(b) Proceed with Steps 19, 20, and 23-26 using the new values of Vol 1T and Vol 2T from Step 39 a. Omit calculations which relate only to P.

(c) Proceed with Steps 32-38, as applicable.

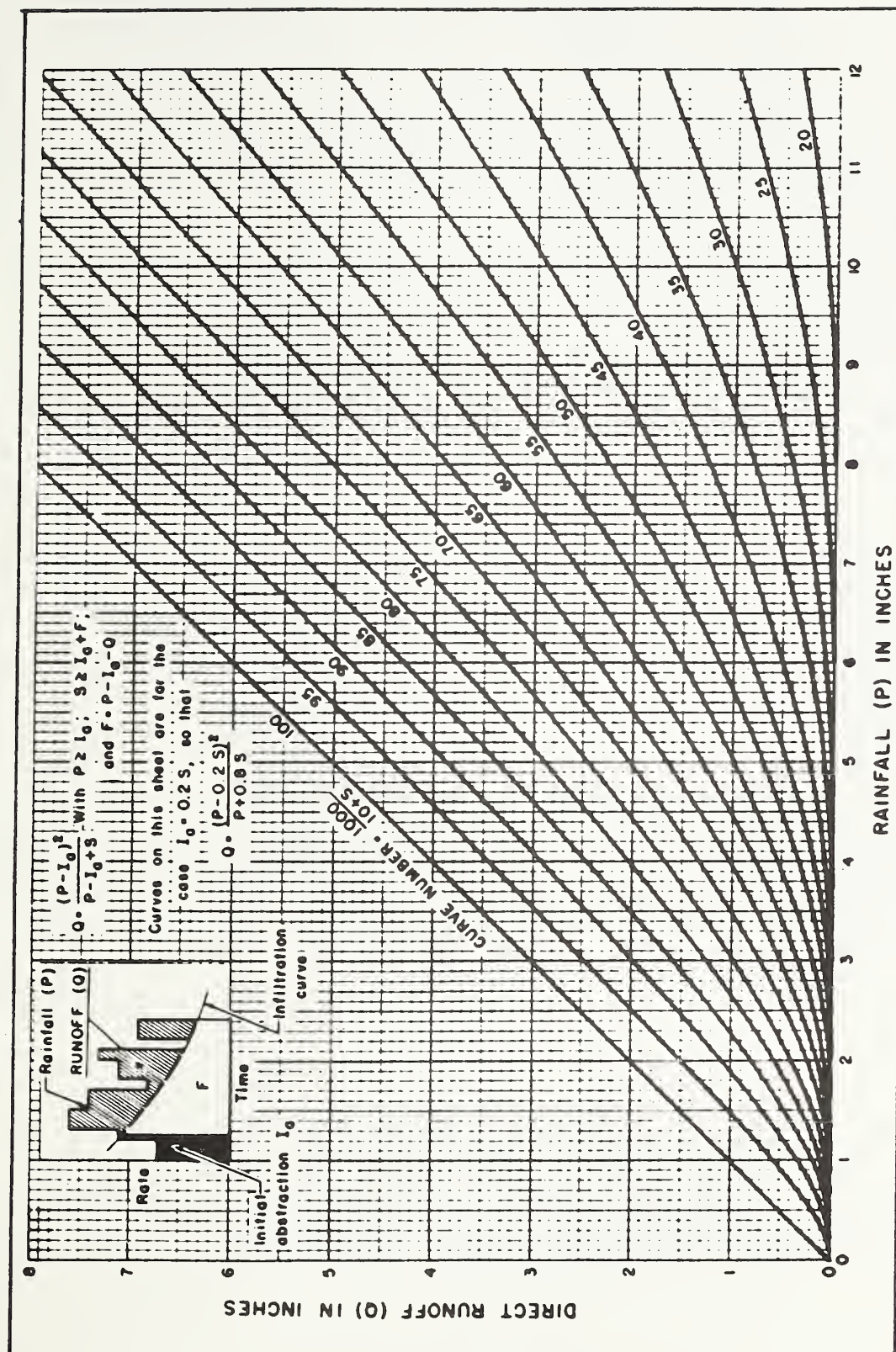


Figure 1.—Soil-cover complex method of estimating direct runoff amounts from storm rainfall.

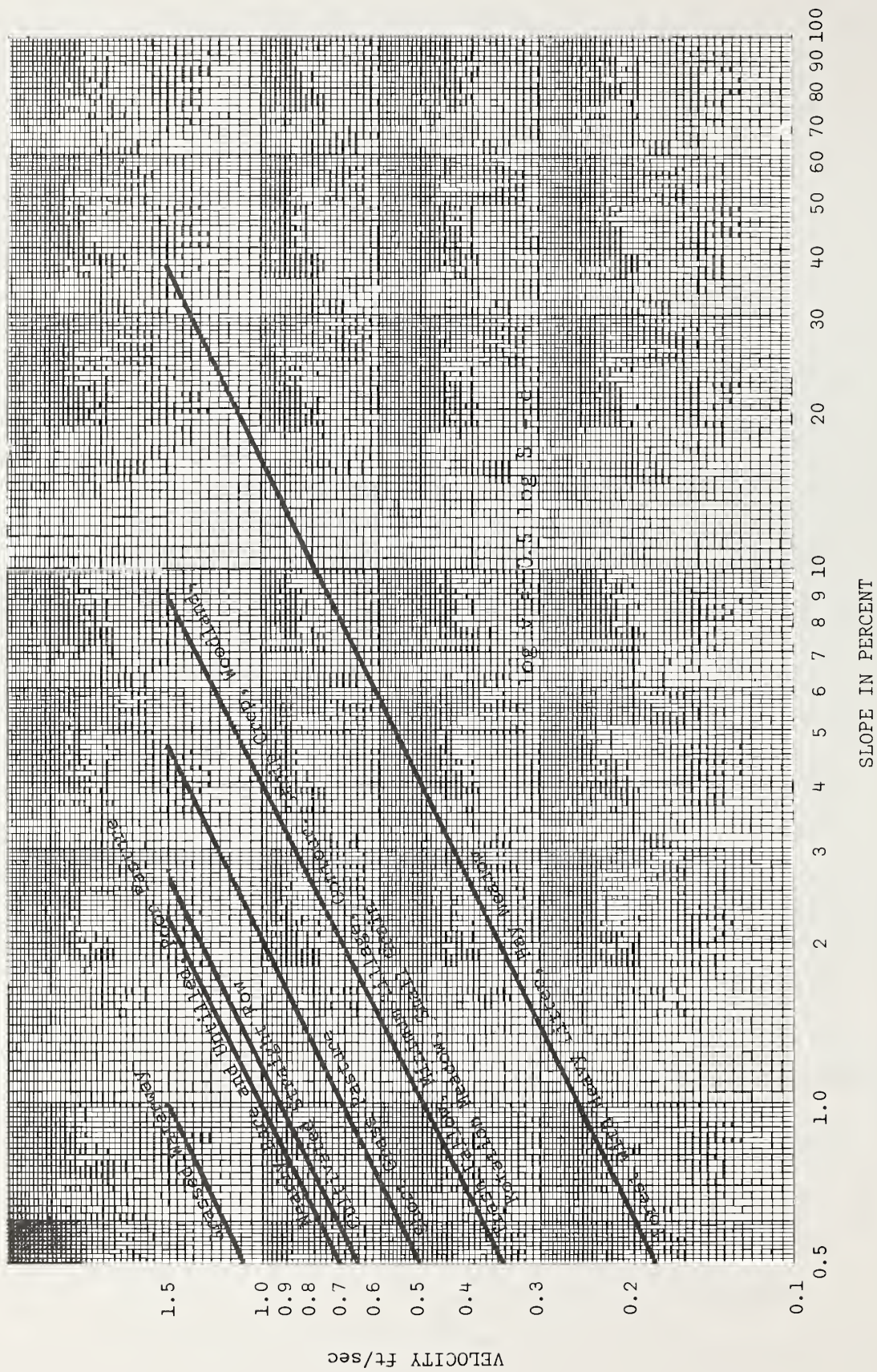


Figure 2.—Runoff velocity versus percent slope for various cover conditions.

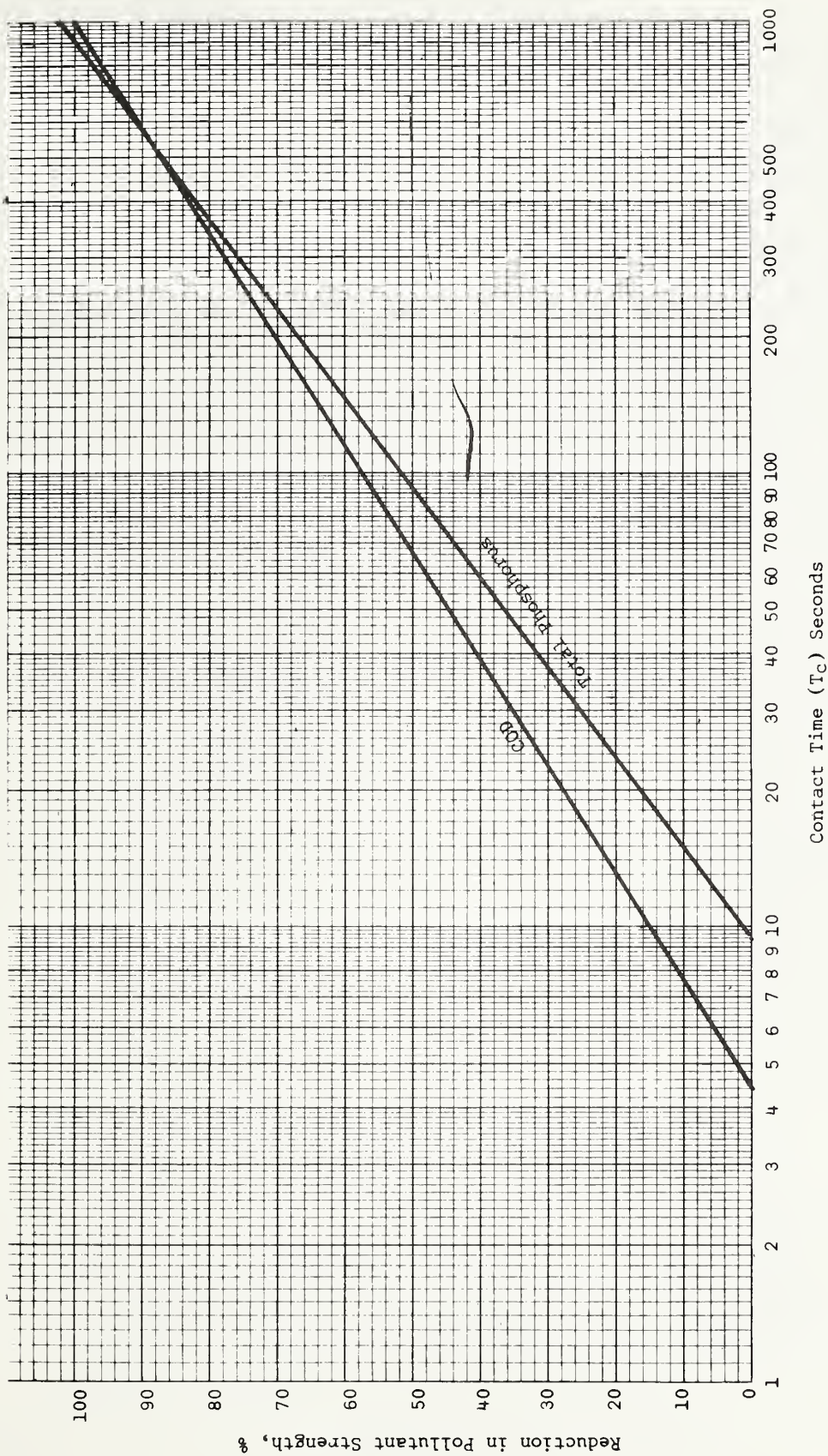


Figure 3.—Reduction in pollutant strength (D) versus contact time ( $T_c$ ) for vegetated filter areas.

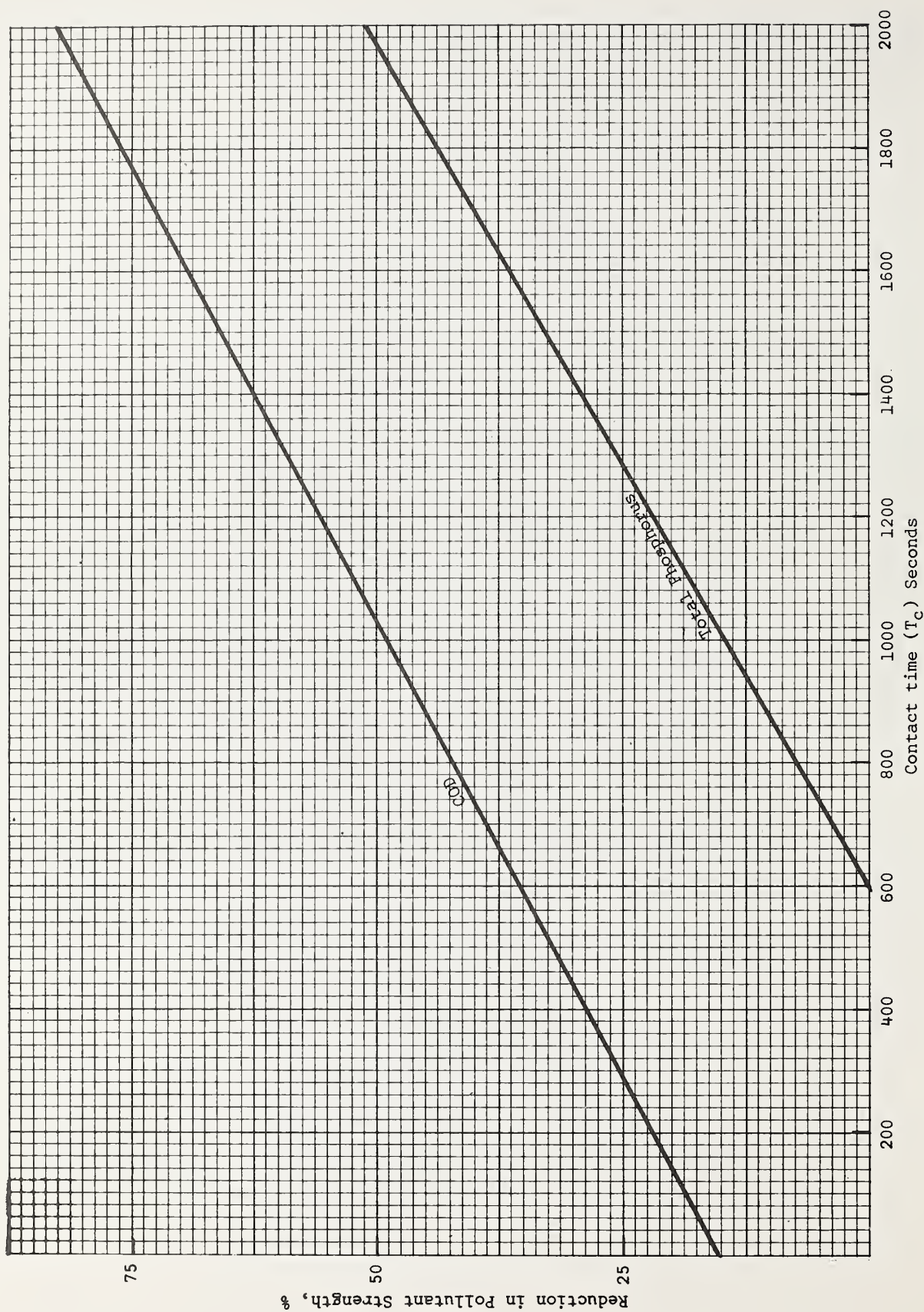


Figure 4. — Reduction in pollutant strength (D) versus contact time ( $T_c$ ) for grass waterways.

## Appendix F

### Notes on the Feedlot Evaluation System

#### Interpreting Animal Lot Ratings

The evaluation system assigns each animal lot a numerical rating for surface-water pollution hazard. These ratings **do not** represent rankings or percentiles. Feedlots will not be evenly spaced in their ratings; more than half of all polluting feedlots are expected to rate between 40 and 70. A rating of zero means the surface-water pollution hazard is negligible or zero. In extreme cases, the rating may exceed 120, but the vast majority of all feedlots will rate less than 90.

A few sample ratings, presented here, are based on the number of animal units (a.u.). An a.u. is one 1,000-lb beef steer or its equivalent in waste generation. Under the recently adopted MPCA rules, the jurisdiction of counties is limited to certain kinds of feedlots with fewer than 1,000 a.u. No Minnesota feedlot smaller than 1,000 a.u. will rate more than 91 under any circumstances. To rate 100, a feedlot would have to be significantly larger than that, at least in Minnesota, where the design (25-year/24-hour) rainfall is moderate. A fictional example of the smallest Minne-

sota feedlot that could possibly rate 100 would be a feedlot for 1,600 a.u., in Freeborn County, where the design rainfall is 5.05 inches. The same fictional feedlot, if located in Kittson County with a design rainfall of 3.85 inches, would rate 94.

The rating is based on a scientific estimate of the amount of pollution generated by the lot and delivered to a receiving water. However, the rating is a statistical abstraction of this estimate and, like EPA gas mileage estimates for automobiles, is to be used only for comparisons.

The actual rating value may be determined in either of two ways. If the COD concentration at the discharge point is 112 ppm or less, the runoff is considered as probably meeting State standards. (State standards require that BOD not exceed 25 ppm, and COD is approximately 4.48 times as great as BOD for typical feedlot runoff.) If the COD at the discharge point exceeds 112 ppm, the rating is determined by a logarithmic formula, based on the amount of COD delivered from the feedlot to the discharge point.

When a single feedlot operation includes several ani-

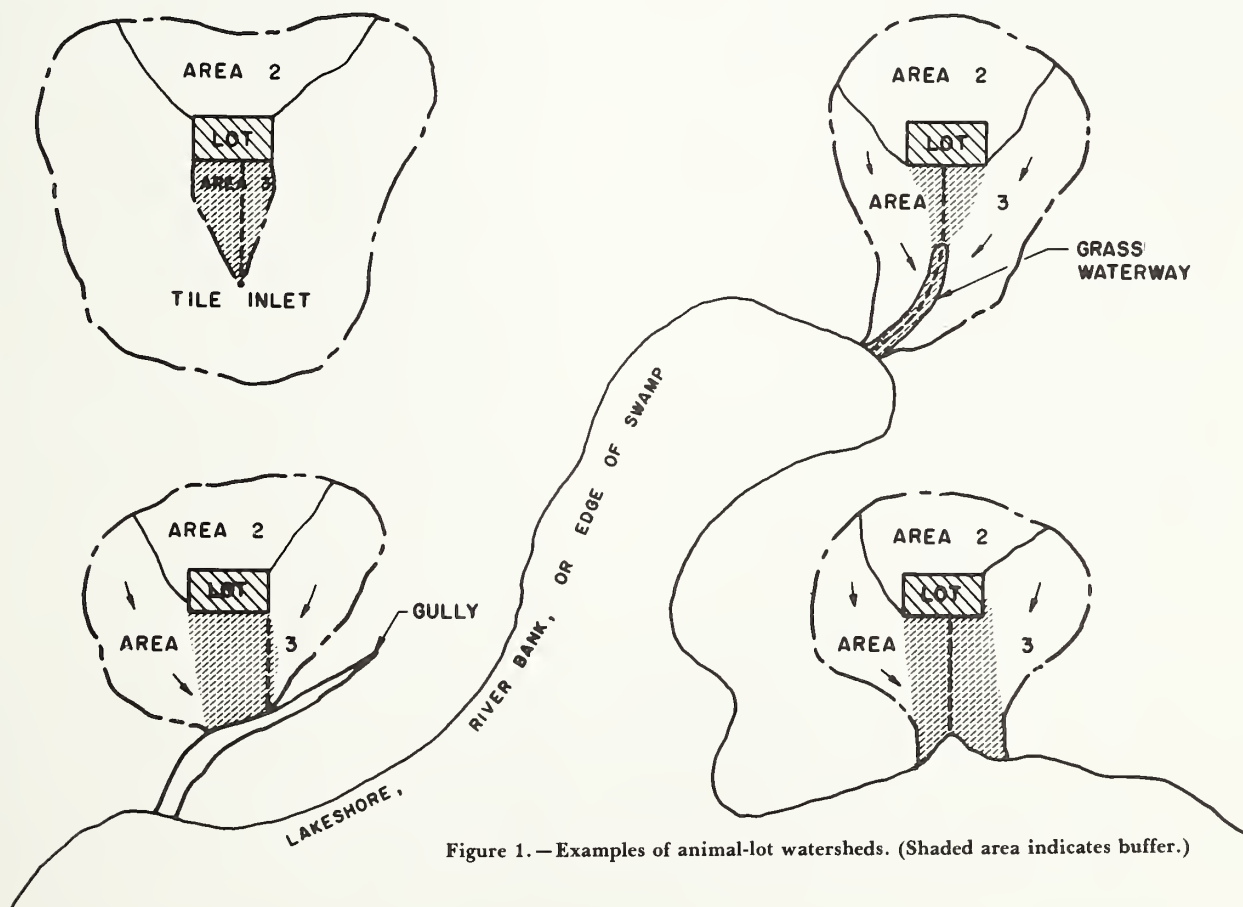


Figure 1.—Examples of animal-lot watersheds. (Shaded area indicates buffer.)

mal lots or animal areas, simple arithmetic **cannot** be used to add the several ratings, except when one of the ratings is zero. A logarithmic method has been provided for this purpose.

### **Determining Area 3 and the Discharge Point**

Area 3 consists of the entire area over which animal lot runoff flows (that is, the buffer), plus any other area whose runoff mixes with that of the buffer.

Runoff from Area 3 mixes with animal lot runoff before it reaches the discharge point. Beyond the discharge point, additional large volumes of water will mix with and dilute it—water from an entire river basin, for example—but this must not be considered as Area 3 (dilution) water.

Another way to look at the situation involves what we might call “flow lines.” These are the lines along which a drop of water might flow; they are at all places perpendicular to the contour. Area 3 is bounded above by the animal lot, below by the discharge point or the edge of a water body, and on the sides by flow lines from opposite edges or corners of the animal lot. Defining the local watershed area, therefore, requires two different approaches. Drainage divides are used in defining Area 2, above the animal lot. Below the animal lot, drainage divides do not apply, and flow lines must be used to define Area 3.

A few sketches (fig. 1) may help clarify flow lines and the delineation of Area 3. Arrows indicate the direction of flow in Area 3, and the heavy dashed line indicates the shortest flow line between the animal lot and the discharge point (same as the total length of all buffer sections). These sketches are simplified versions of real situations, and they are intended only to help guide the users professional judgment.

Because of the great variations between actual feedlot sites, we often have difficulty determining the discharge point for a given situation. The key to valid evaluations is, therefore, consistency in identifying the discharge point. Extensive in-the-field training is essential so that **all** personnel evaluating feedlots in any one county or State use consistent criteria.

### **Buffer Effectiveness**

The length, ground cover, and slope of the land between an animal lot and the discharge point determine the effectiveness of a buffer in controlling animal lot pollution. Water in a buffer passes as sheet flow over the land in close contact with the soil and vegetation, facilitating settling, adsorption, interception, and infiltration of the pollutants. Buffer effect depends on the time during which the water is in contact with the buf-

fer surface before entering a channel or flowage. Therefore, length of the buffer has the largest influence on its effectiveness, followed, in turn, by the character of vegetative cover and slope.

Overland flow generally concentrates into a channel within 300 to 500 feet of its origin. If a longer buffer is to be effective, it may be necessary to ensure maintenance of sheet flow by regrading cropland, constructing level spreaders, or other means.

A grass waterway scarcely provides sheet flow and is, therefore, a far less effective buffer (from one-half to one-tenth) as a land surface over which sheet flow occurs. However, a formula reflecting the effectiveness of a grass waterway in reducing animal lot pollution has been incorporated to enable the model to be used for design.

For any buffer other than a grass waterway, a length of about 1,700 feet as sheet flow will invariably be sufficient to reduce the COD concentration to less than 112 ppm, ensuring a zero rating. (As noted above, such a long buffer ordinarily requires measures to ensure the maintenance of sheet flow.) A shorter buffer may suffice if the animals are not packed very densely on the animal lot; the screening formula is based on this fact. While a shorter buffer may also suffice if it is heavily vegetated or relatively flat, these factors were not included in the screening formula because of the expertise required for their determination.

The screening formula cannot be used where a grass waterway serves as a buffer.

### **Evaluating Manure Stacks**

If manure is stacked within an animal lot, no special consideration is necessary. The animal lot should be evaluated just as it would be if the manure was spread over the entire animal lot.

If manure is stacked outside an animal lot, the Animal Lot Evaluation Data Form should be completed, as if the manure stack were an animal lot. The information on Areas 2 and 3, on the buffer section(s), and on the number of animals whose manure is stacked, should all be collected in the usual way. To recognize the fact that it is a manure stack, however, Area 1 should be doubled before entry on the data form. The curve number of the manure stack is 91.

### **Adjusting for Loafing Areas**

When an animal lot is used for a loafing or exercise area and, thus, is not occupied 100 percent of the time, the AUD used in the evaluation should be adjusted. This can be done by multiplying the number of animals by the percent of time the animal lot is occupied and entering this value in Step 8 of the evaluation form.







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